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Nematodes in Connection With Sugar Cane Root Rot in the Hawaiian Islands

BY FREDERICK MUIR AND GERTRUDE HENDERSON, M. B., CH. B.

PREVIOUS WORK IN HAWAIIAN ISLANDS

What part nematodes play in the root trouble of our sugar cane has been under consideration by our Experiment Station for a number of years. In 1906, Dr. N. A. Cobb[1] commenced work on this problem; he described twenty-three species of nematodes found living in the soil around the roots of sugar cane and pointed out the probability of their playing a part in the death and decay of sugar cane roots. These were the first free living Hawaiian nematodes to be studied and described. In 1909, Dr. Cobb[2] reported two nematodes found living within the roots of sugar cane, *Heterodera radicicola* and *Tylenchus similis* Cobb[3], and commented upon the damage done by them. In 1910, L. D. Larsen[4] reported *Heterodera radicicola* in pineapple roots and remarked upon the damage and remedial measures. In 1911, Dr. H. L. Lyon[5] pointed out the increase of *Heterodera radicicola* when certain varieties of beans were used for green manuring. Since then a number of references to this subject have been made in the *Planters' Record* and the Monthly Letter of this Station.

A year ago a combined study of the root rot problem, or problems, was undertaken by the chemical, agricultural, pathological and entomological departments of the Experiment Station and is still being carried on. The following

1 H. S. P. A. Experiment Station Bull. 5, Pathological Series, 1906, pp. 163-195.
2 H. S. P. A. Experiment Station Bull. 6, Pathological Series, 1909, pp. 51-74.
3 This was described as *Tylenchus biformis* Cobb, but was subsequently found to be the same as *Tylenchus similis*.
4 H. S. P. A. Experiment Station Bull. 10, Pathological Series, 1910, pp. 62-68.
5 *The Hawaiian Planters' Record*, V, October, 1911, pp. 200-202.

notes on some aspects of the nematode portion of this study are intended for the information of field men on plantations who are interested in the subject.

General Remarks

Nematodes—commonly referred to as thread worms, round worms, wire worms, etc.—constitute one of the largest groups of animals in existence and comparable only to the insects in the number of species. They are the most ubiquitous of all animals for they are found living everywhere except in the air, and even there they are found blown about by the wind in a dehydrated or encysted condition. As free living animals they are found from the Arctic to the Antarctic, and from the tops of mountains to great depths in the oceans; they live equally well in fresh and in salt water. As parasites they are found living in every group of vertebrates and in many invertebrates, while others are parasites in plants. Over twenty species are known to be parasitic in man and of these the most dangerous are Filaria, hook worm and Guinea worm. All our domestic animals are subject to attacks from these parasites and a great many of our plants suffer from a similar infestation, resulting in losses which are enormous in the final count.

In spite of the great importance of the role played by these little creatures in man's economy their study has been sadly neglected, only a few species affecting man or some of his domestic animals being fairly well investigated. This neglect not only relates to the lives and habits of these creatures but is also reflected in the condition of the classification or arrangement of them into orders, families, genera and species, a work that necessarily precedes extensive study of the various species.

The chief causes of this neglect are the minute size of most of the species, obscure habitats, the difficulty of catching, preserving and preparing the specimens for examination and the absence of a good modern textbook. This last should be remedied as soon as possible, as a good, well illustrated work, along with a full, up-to-date catalogue would cause our knowledge to be increased a hundredfold in a few years. Nevertheless, such a work must give equal importance to both the free living and parasitic forms, and not treat the former, which constitute the majority, as of little or no importance.

Appearance and Structure

To the average observer, the term "thread worm" roughly describes the external appearance of these animals. Mostly minute, long, cylindroid organisms, with little or no signs of appendages, whitish or translucent, the head bluntly rounded and the tail either short and bluntly rounded or longer and more drawn out. They differ from earth worms in having no segmentation and so they cannot progress by an alternate longitudinal contraction and elongation, but move forward by a sinuous snake-like movement from side to side. Some species lash themselves from side to side most vigorously, even when attached to a solid surface by the gland at the end of their tails. They can move equally well through the tissues of their hosts, through water or in the soil. In size they

vary from less than one twenty-fifth of an inch to fourteen inches, the free living forms being small, while the giant forms are all parasitic.

While to the casual observer nematodes appear structureless, and are too often illustrated as such in textbooks and medical works, when properly prepared and seen under a high power microscope they are seen to have a complex structure. The mouth is situated at the anterior extremity and is generally closed by two or more lips which may be plain or bear small papillae or setae. The mouth leads either directly into a muscular oesophagus or into a pharyngeal cavity which may be either plain or armed with teeth or other hard structures, the nature and arrangement of which are of importance in classification and, to a large extent, indicate the nature of the food. The intestine is continuous with the oesophagus and is straight, reaching almost to the tail where it joins the anal opening. The excretory system consists of two canals, one on each side, embedded in the lateral thickenings of the subcuticular tissues, joining together and opening on the ventral surface in the anterior end. A "poison gland" also opens at the same place in many forms. In many species a large salivary gland opens into the lumen of the oesophagus a little way behind the junction of pharynx and oesophagus.

On each side of the body, on the lip or head or slightly behind the head, there is an organ called the amphid or lateral organ which leads into the amphidial pouch. These latter run back on each side for some considerable distance and their walls are connected with nerves. These organs have been found on a great number of species and it is probable that they are universal or nearly so. The prevalence of the organs together with their complexity indicate that they are of some importance in the economy of the animal and good reasons have been given for considering them as sense organs by which they are guided to their food and to the opposite sex. It is probable that they respond to chemical stimuli and thus act as our sense of smell and taste. The fact that nematode parasites in animals can find their way to certain tissues, and others in the soil can soon find suitable roots, shows that they must have very efficient sense organs to direct them, and the fact that the sexes can find one another also indicates that they must have directive sense organs of an efficient nature.

The sexes are separate. The female opening is on the ventral side at some point between the opening of the excretory duct and the anus, the position varying in different species; there may be either one or two ovarian tubes and these are comparatively large. The male genital opening is at the anal opening and the sex is generally recognizable by a paired or a single organ, the spicula. The mode of reproduction varies; generally eggs are produced, but in some cases living young; some species first produce spermatazoa, later produce eggs, and she, or he, then fertilizes her own eggs. The number of eggs produced also varies in different species and in some cases is exceedingly great, Van Beneden having computed that as many as 60,000,000 were present in one nematode.

Nematodes Parasitic Upon Plants

We have previously remarked that the nature of the armature of the pharynx indicates the nature of the food. This is distinctly so when we consider those

nematodes which feed upon the juices of living plant tissues. So far as our present knowledge extends all such nematodes are armed with a hollow needle or style, similar to the hollow needle of a hypodermic syringe; the apex is always oblique, as in a hypodermic syringe needle to give it an acute apex and so enable it readily to penetrate the plant tissues. This style arises from the bottom of the pharynx and the hollow through its length forms the only opening into and is continuous with the lumen of the oesophagus. The base of the style is either plain or produced into a trilobed bulb; muscles are attached to the base and proceed to the walls of the body, enabling the style to be thrust forward. The with-

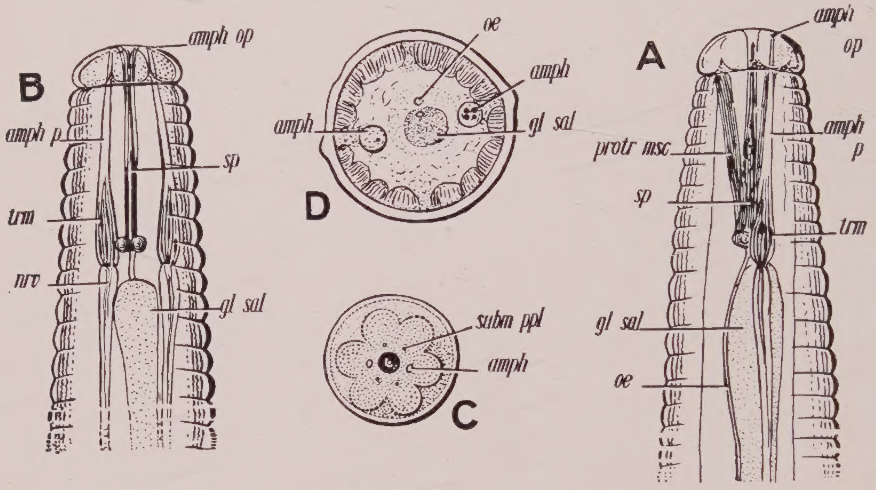


Fig. 1. *Tylenchus dipsaci.* A. Ventro-submedial view of head end. B. Ventral view of head end. C. Front view of head. D. Cross section through the region behind the spear. *Amph op*, amphidial opening; *amph p*, amphidial pouch; *nvr*, apparently amphidial nerve fibres; *oe*, oesophagus; *protr msc*, protractor muscle of the spear; *sal gl*, salivary gland; *sp*, spear; *trm*, terminals. (From Steiner.)

drawal is most likely effected by the contraction of the muscular oesophagus or the muscles of the pharynx. If the lips are fastened to the plant tissue by suction such an arrangement of the muscles would allow of considerable pressure being exerted upon the style.

This piercing organ is always referred to as a "spear" but the term is inadequate as it does not indicate its hollow nature; a term indicating this, such as syphanostyle, is desirable.

The fact that all nematodes truly parasitic upon the living tissues of plants are armed with such a hollow style simplifies our problem, as we can exclude from our main study all those that do not possess one. All nematodes having such a hollow style found in soil around living plant roots, or on leaves or stems, must be under suspicion and experimented with under controlled conditions.

Remarks on Some Local Species

Cobb reported eleven nematodes bearing hollow styles, two of which penetrate into the roots. This does not exhaust the list, as some not reported by him have since been discovered and many more await the investigator. Four of the

species most often found associated with cane roots are mentioned below, others will be reported upon as our knowledge increases.

The Root Gall Nematode, *Heterodera radicicola* (Greeff)

This nematode is now found in nearly all tropical and the warmer parts of temperate climates. Its original habitat is now difficult to determine as it has been carried about by commerce to such a large extent. The wide distribution of this nematode, the large number of plants, both cultivated and wild, which it is reported to attack, the harmful effects it has upon many of its hosts and the lack of any effective measures to control it on a large scale, has made this species the most notorious of the nematodes that attack plants. During the last thirty years much has been written about it but still there are points in its life which we do not fully understand.

The young female in the soil is almost colorless, threadlike, and measures one-fiftieth of an inch or less. Compared with many free living nematodes it is

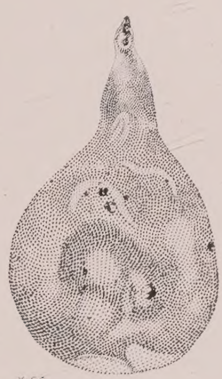


Fig. 2. Large gravid female of *Heterodera radicicola*. (From Cobb.)

not very active but it can soon effectively reach roots suitable for its future home. It is probable that chemical activity at the growing points of the roots is the chief attraction and nerves situated in the walls of the amphidial pouches are the means of perception of the stimulus. The rapidity with which young plants are attacked and the strong sense of host selection which the parasite shows indicate that its sense organs must be efficient. Having found a suitable host root it penetrates as a rule at or near the tip. In sugar cane growing in badly infected areas we have found the first half inch of every young tip to contain from two to twenty young nematodes. The hollow style with its sharp apex is a suitable instrument to penetrate into the root, but once in the young nematode appears to work its way between the cells, especially when moving in the direction of the axis of the root. Having arrived at a suitable position in the young cane root, either in the cortex or the stele, it settles down for life; its food, consisting of the contents of the plant cells, is sucked through the hollow style; the muscular oesophagus, more especially the bulb, serving as a pump to propel the cell con-

tents into the intestine. At first it grows longer, but later it grows fatter till at last it is a small, round, shining, opaquely white body about the size of an ordinary pin's head, with a small protuberance at the head end. The effect of the presence of the nematode upon the plant tissues is interesting; the cells around the head enlarge and contain several nuclei, their increase causing the root at that point to swell up into the conspicuous gall which has given the nematode its popular name. The eggs, varying in number from about forty to some four hundred, remain in the mother nematode where they develop. If the host tissues

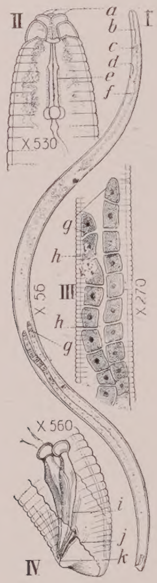


Fig. 3. Male of *Heterodera radicicola.* I, worm in profile. II, head of same more highly magnified. III, middle region of the worm to show the blind ends of the two sexual organs. IV, posterior end. *a*, lips; *b*, oesophageal tube; *c*, median bulb; *d*, excretory pore; *e*, spear; *f*, intestine; *g*, *blind* end of testicles; *h*, testicles; *i*, spicula; *j*, rudimentary bursa; *k*, anus. (From Cobb.)

be suitable the young break forth from the skin of the dead mother and remain in that locality, but if the host tissues be not suitable then the young set forth in search of a new root. While in the mother skin the eggs or young appear to be able to undergo a great deal of desiccation and remain dormant for a considerable period. The cause of the formation of the gall is obscure; the simple mechanical irritation due to the presence of the nematode does not appear to be the stimulus which causes the plant cells to develop so abnormally, as other nematodes (i. e., *Heterodera schachtii, Tylenchus similis*) live in the root tissues and do not cause a gall. It is therefore possibly due to a secretion, probably derived from the salivary gland.

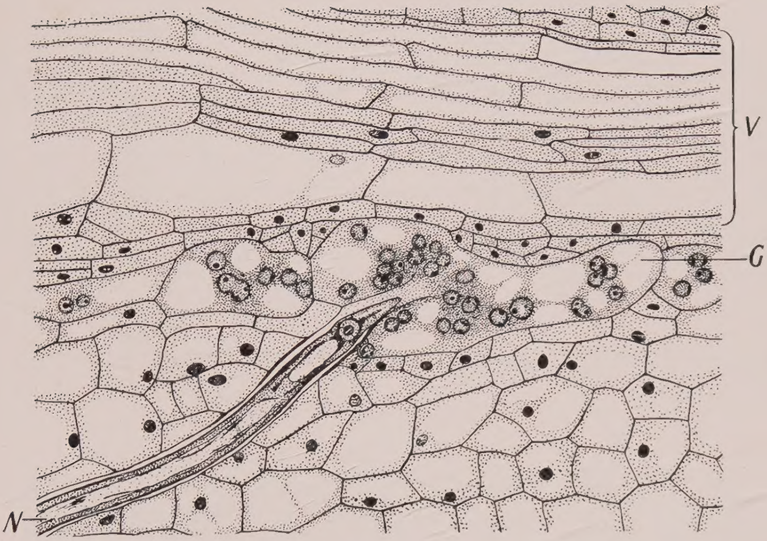


Fig. 4. Young female *Heterodera radicicola* in a section of gall on root of Lahaina cane. N, nematode; G, giant cell with many nuclei; V, vascular tissues. (From H. L. Lyon.)

The development of the male is not quite the same as the female. It seeks the young roots in a similar manner and increases in size but does not become rounded and stationary. When fully grown it seeks the female.

In some roots the galls remain firm in spite of the presence of numerous nematodes. In the sugar cane roots the galls usually break down, especially when situated at the apex, and the root dies back. Often lateral rootlets grow out above the apex, but these soon become infested and the roots cease to function. In the pineapple root the galls also break down and the root decays.

Fungi are nearly always present where nematodes are numerous and they must play some part in the ultimate destruction of the root.

Nematodes have been proved to show a strong tendency to host selection. If a strain of nematodes is reared for several generations upon a certain species or variety of plant they become so strongly attached to that host that they will not change to another. If an area heavily infested with a strain of nematodes which has been reared upon a certain host, A, be planted with a different host, B, the vast majority of the nematodes in that area will die rather than enter the new host B. Or if A and B be planted together B will be very slightly attacked while A will be very heavily infested. Thus B will at first show a strong "resistance" to nematodes, but if grown long enough in that locality may eventually suffer as severely as A.

This problem of host selection is not peculiar to nematodes but is found also among insects. Aphids or plant-lice show this very strongly, as has been demonstrated at the Station with *Aphis maidis,* the corn aphis which carries mosaic disease.

Fig. 5. Galls of *Heterodera radicicola* on Lahaina. (From H. L. Lyon.)

Fig. 6. Galls of *Heterodera radicicola* on Yellow Caledonia. (From H. L. Lyon.)

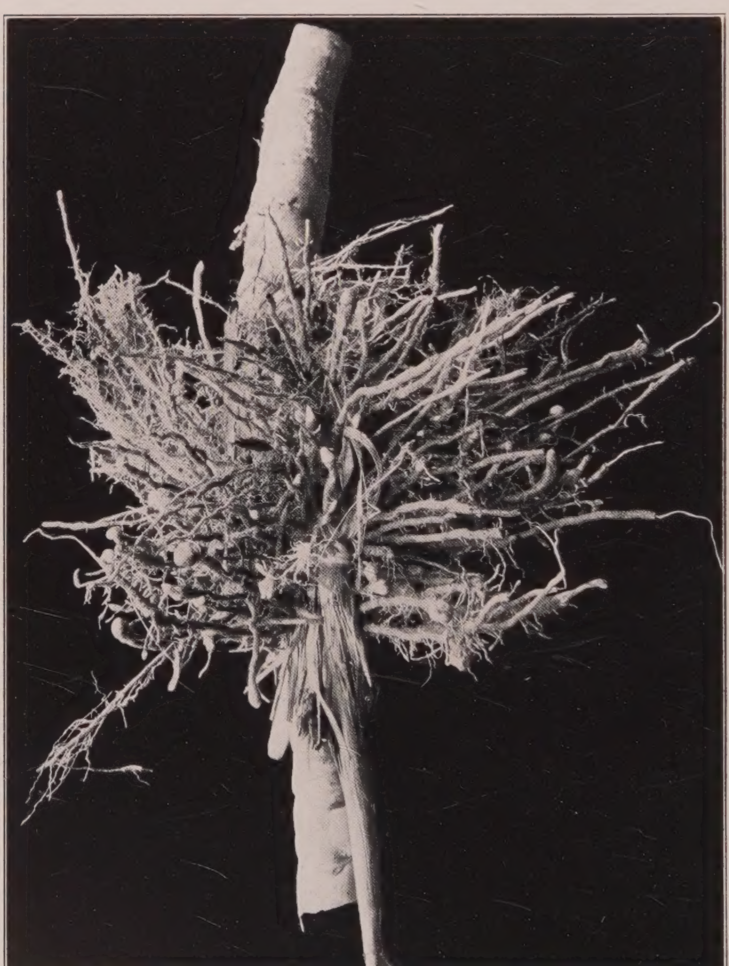


Fig. 7. Galls of *Heterodera radicicola* on H. 109. (From *Planters' Record*, XX, No. 5.)

Heterodera (especially *H. schachtii*) may remain in the soil in the encysted form for a long period if suitable growing roots are absent. This indicates that the roots produce a stimulus which causes the nematodes to start an active career.

THE BEET NEMATODE, *Heterodera schachtii* (SCHMIDT)

This species of nematode has not been reported from such a wide area as *H. radicicola* but it is quite possible that it has not yet been distinguished from the more widely distributed species as it can be easily confounded with it. It is only recently that the two species have both been recognized in the Hawaiian Islands.

It has attained its popular name of "beet nematode" on account of the damage it has done to that crop in Europe and America. It has been reported on a number of species of plants, many of economic value.

When living in the roots of beets its life history differs somewhat from *H. radicicola.* As she grows larger the female emerges from the tissues of the plant and remains attached to the root by her head; here, when fully matured, she eventually assumes the hard brown cyst form in which the young develop. In sugar cane the nematode does not leave the tissues of the root but lies surrounded by the root tissues which do not develop into a gall. In this brown cyst stage the eggs or young can remain for a long period if conditions are not favorable, or

Fig. 8. Root of sugar cane attacked by *Tylenchus similis* Cobb. (After Cobb.)

suitable food is absent from the soil. The eggs in the brown cyst do not always hatch out at once, but a few at a time over a period of many months. A dry heat at 145° F. kills them, even in the brown cyst stage.

Experiments have shown that the young of this species can travel ten feet (about 8,400 times their own length) in two weeks when in search of food. A single female can produce from 300 to 400 eggs and the time from one generation to another is about four to five weeks.

In sugar cane this nematode does not show a preference for the tips of roots but attacks them at any point. Its effect upon the root is to cause the cortex to break down, and the stele to become infected by a fungus which appears always to be associated with it.

As it does not produce a gall on the roots its presence is often overlooked and it can only be recognized by breaking open the cortex.

The Burrowing Nematode, *Tylenchus similis* Cobb

This nematode and its effects upon the roots of cane were described by Dr. N. A. Cobb in 1909. The young enter the cane roots in a manner similar to the two species of *Heterodera* and continue their development among the tissues of the root where one generation will follow another till such time as the root is broken down and made unsuitable for living in. A generation takes from four to five weeks in pot cultures in the laboratory. They produce eggs but the numbers are not known. They remain active all their lives and appear to attack and destroy the surrounding cells and form a chamber in which they live. The roots attacked show no signs of producing galls. The tissues around the point of entrance soon become discolored light red which spreads out and becomes

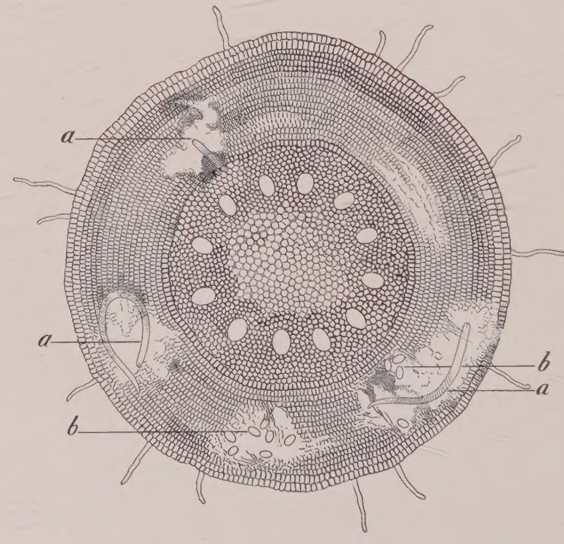


Fig. 9. *Tylenchus similis* in root of D 1135.
a, nematode; *b*, eggs.

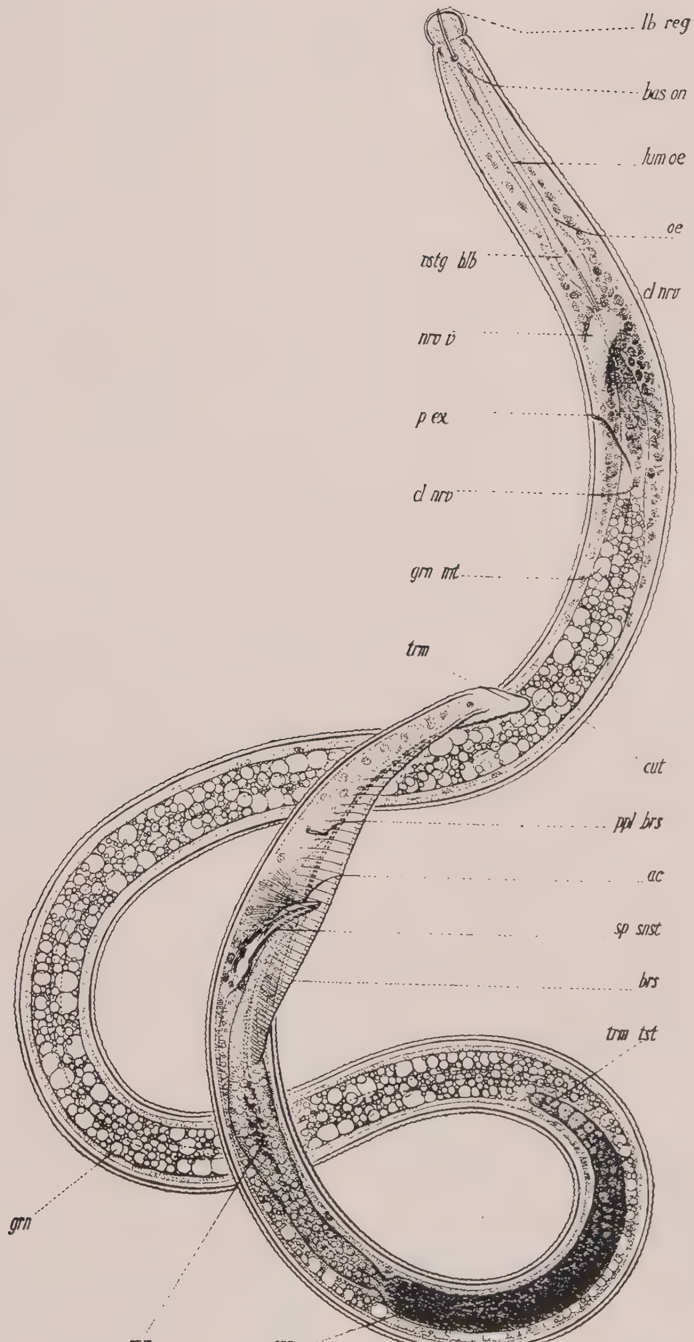


Fig. 10. Male of *Tylenchus similis* Cobb. *lb reg*, lip region; *bas on*, base of spear; *lum oe*, oesophageal lumen; *oe*, oesophagus; *vstg blb*, vestige of bulb; *nvr r*, nerve ring; *p ex*, excretory pore; *cl nvr*, nerve cell; *grn int*, fat granules of intestine; *cut*, cuticle; *trm tst*, end of testi; *spm*, spermatozoa; *brs*, bursa; *sp snst*, spiculum; *ac*, accessory piece; *ppl brs*, bursal papilla. (After Cobb.)

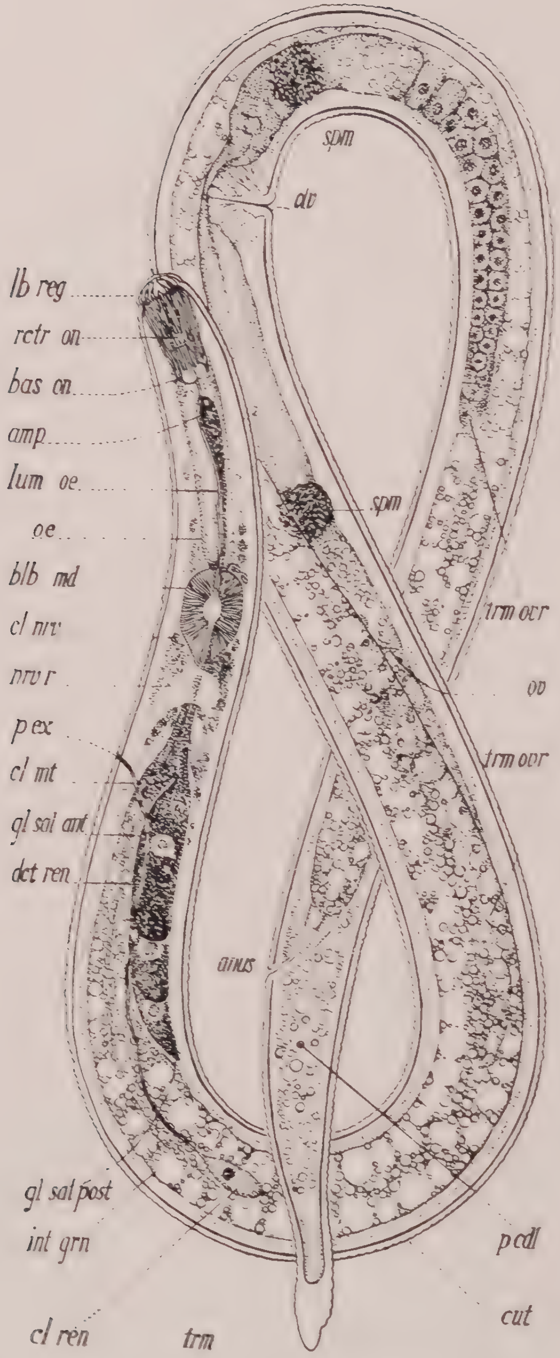


Fig. 11. Female of *Tylenchus similis* Cobb. *retr on*, retractor muscle of spear; *amp*, ampula; *blb md*, median bulb; *gl sal ant*, anterior salivary gland; *dct ren*, renette duct; *gl sal post*, posterior salivary gland; *cl ren*, renette cell; *trm ovr*, end of ovary; *ov*, ovary; *spm*, sperm; *dv*, vulva; *anus*, anus; *p cal*, caudal pore. Other letters same as in male. (After Cobb.)

darker in color. A fungus always accompanies this nematode in the root tissues which, when cultured, has the same color as the discolored tissues. It is possible that the breaking down of the cell walls where the nematodes dwell may be due to the action of a secretion, although it is quite possible that it is due to the direct mechanical action of the moving nematode.

The bad effect of this nematode upon cane roots has been demonstrated in both large and small pot experiments, and clear cases of growth failure in the field have been traced to them. In some cases not an inch of root has been found free from their attack, and all but the most recent roots were dead. In some cases many hundreds of these pesky little beasts have been found in less than an inch of root.

It is difficult to recognize the work of this species once the roots are broken down and have been deserted. The effect is plainest in plant cane of about six to ten months old.

The same species has been found living in nut grass in the Hawaiian Islands and Jamaica, and in banana roots in Fiji.

External or Semiparasitic Nematodes

The nematodes included under this heading differ from the former three in that they do not enter into the cane roots, but pierce the root from the outside and suck the plant fluids. The point attacked becomes discolored in a manner similar to the lesion made by *Tylenchus similis*. The largest, and the commonest, species found in the soil around sugar cane roots is a species of *Axonchium*. In our experiment pots the effect upon the roots is similar to that of *Tylenchus similis* but less severe. The direct damage done by these nematodes is not likely to be very severe, but the lesions made by them give entrance to fungi and so, indirectly, they may play an important role in the root rot problem.

The lesions made by nematodes are more generally infected with fungi than the pits made by insects, snails and centipedes, and it is possible that nematodes convey the fungus spores about with them. The spores of some of the fungi can pass through small earth worms common in the soil without losing their vitality and it is possible that they can pass through the nematodes likewise.

A species of *Xiphonema* is found in the soil in small numbers. This genus possesses a long style which is a very effective weapon for attacking the roots, but as it has only been found in small numbers it can therefore play but a minor part in the root rot problem.

Two species of *Criconema* have been found at times in fair numbers.

Cobb reports eight species of *Dorylaimus* but our researches so far have shown very few.

The effect of all these nematodes on cane roots is similar and they must be responsible for the many little lesions found on cane roots in which no nematode can be discovered. As they have all been found in close association with the sugar cane roots there is strong reason to believe that these constitute their food in the field; in experiment pots *Axonchium* lives on sugar cane roots and increases very rapidly.

Some General Considerations

Localization of Severe Infestation

In the Hawaiian sugar cane fields the severe attacks by nematodes are strictly localized. Although they may be generally distributed in lesser numbers over the whole field, yet it is only in fairly well defined spots that they increase to a severely harmful extent. The reason for this localization appears to be in the soil condition, as the same variety of sugar cane may be grown over the whole area. What this condition is we cannot say at present, but an understanding of it might have practical application. At first it appeared as if alkalinity and acidity might be the controlling factors but further field observations disclosed too many exceptions.

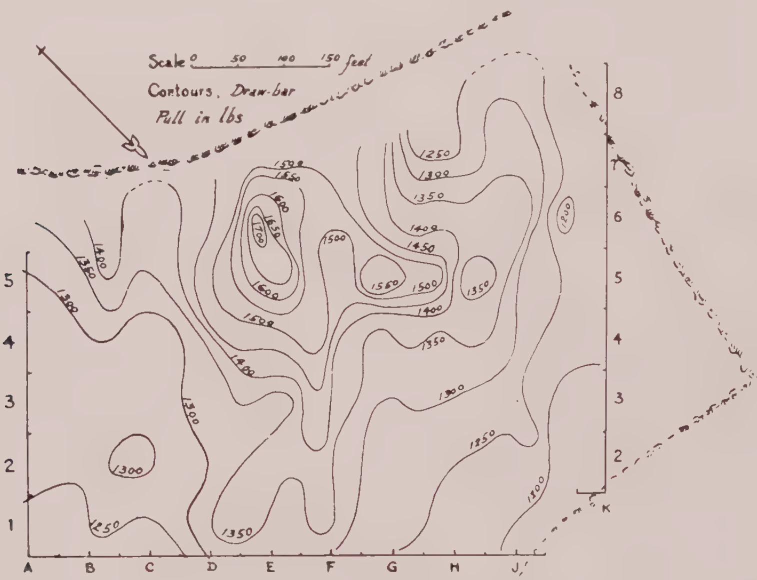


Fig. 12. Lines of equal draw-bar pull over a supposedly uniform field. (After Keen.)

It is possible that the physical condition of the soil may play an important part in this matter. Work done elsewhere may be of interest to us in this matter. In England the drag or pull of the plow has been studied, chiefly in regard to economic speed in plowing. A self-recording instrument is fixed between the plow and the horse or tractor which registers the distance, speed and the pull. This pull depends upon the physical nature of the soil. These records can be plotted and the differences displayed. It was found that many fields which were flat and apparently uniform were physically very diverse; there would be centers of high or low resistance which would graduate out, so that the chart looked like contour lines illustrating elevation. Such charts of some of our own fields, made by such an instrument, or by other means, might throw light on our nematode localization problem and on other matters.

Connection Between Nematodes and Our Lahaina Disease

It has been pointed out by several workers at the Station that "Lahaina disease" is not a single problem but a complex of problems, the causes being several, working either singly or in groups. As has been stated above, nematodes are always associated with fungi and it has been so far impossible to get a culture of nematodes on growing sugar cane roots without the presence of one or more species of fungi or bacteria. In some cases we have found cases of growth failure and root rot where, for practical purposes, no nematodes were found but fungi were present; in other cases neither nematodes nor fungi could be demonstrated to be the active cause, but soil conditions appeared unfavorable. At the Station there are a number of records in which growth failure has been clearly traced to nematodes, and our present work has added considerably to this evidence; the same fields have been shown to have been infected for a number of years in which growth failure has been present in a lesser or greater degree the whole time.

The present nematode survey will have to be greatly extended before we can speak finally upon this subject, but enough evidence has now been collected to demonstrate that a considerable portion of our growth failure is due to nematodes. How far they were responsible for eliminating Lahaina over large areas in the past we cannot say. If patches of Lahaina were planted in some of these areas and the results watched closely we might be able to draw more accurate conclusions.

One of the most vital questions on many of our plantations today is whether we shall ever have an H 109 problem similar to the "Lahaina disease" problem. This we cannot say at present, but anything that elucidates the latter will enable us to foresee and, perhaps, ward off the former.

The nematode problem is not confined to the sugar industry but is an important one to the pineapple industry and, perhaps, even a greater one to other forms of agriculture, such as truck gardening. That these small and obscure animals are a limiting factor in growing many sorts of vegetables is evident to anyone who has tried to grow them in his yard. Without nematodes we should get quite one hundred per cent more for our labor than we do.

Problem of Control

From an economic standpoint, this question is the most important of the phases of the nematode problem, and, unfortunately, so far no permanent form of control has been discovered. Even temporary palliatives have as yet been unsatisfactory, chiefly owing to our lack of knowledge of the life history, habits, and senses of these small creatures whose lives are passed in the soil.

Resistance, Changes of Varieties and Agricultural Methods

This question has been greatly obscured in the past because the strong "host selection" factor was not appreciated, and much contradictory evidence was accumulated which has only recently been understood. Undoubtedly there are some

varieties of plants which are less susceptible to attack and others which are less able to withstand attacks. The damage to sugar cane is proportional to the number of nematodes attacking and the power of the plant to send out new roots. Thus relief could be looked for along two paths, viz., varieties which are resistant to attacks or which have vigorous root systems, and agricultural methods promoting the root growth. As the destruction of the roots brings about starvation of the plant so any small degree of lack of water will be felt severely by nematode infested plants, thus the water-holding power of the soil is important. Organic manures around the roots of infested plants should be of service.

It has yet to be shown that the host selection principle plays any part with our different varieties of sugar cane, but the fact that a change of varieties has shown good results makes such a thing probable.

From what we know of the life of our nematodes at present clean fallow is of little value and this was well shown by an experiment at Waipio where a plot of land infected by nematodes was divided into two parts, one sown to Jack beans and the other left clean fallow for a season. Both plots were then planted to Lahaina cane and the one planted to Jack beans gave a very marked increase over the one left to clean fallow. It is possible to explain this as follows: The nematodes in the clean fallow plot remained dormant until it was planted to cane, but the nematodes in the plot planted to Jack beans were stimulated to activity by the growing bean roots but refused to enter them and so perished.

Trapping

This method of control has been as successful as any and is founded upon a knowledge of the life history of the nematode. It is only applicable to those forms which enter into the roots. As it takes about five to six weeks for the nematodes to mature it is possible by planting a crop which they like and by destroying it before the nematodes have time to reach maturity, to trap and destroy them before they can produce another generation. By repeating this process twice or three times the soil can be greatly relieved from nematodes. By what we have said re host selection it is best to use the same plant for the catch crop as was formerly grown on the land. Some of the good experienced by this method may have been due to rotation and not to trapping; the nematodes may have hatched and died, but not entered the "trap."

Rensch in Germany reports that he has extracted two substances from roots which, when placed in the soil, causes the nematodes to hatch out. Such substances placed in clean fallow soils would soon clear them of nematodes. If this be correct and the substances can be produced on a commercial scale then the greatest advance has been made towards nematode control.

Poisons

A great amount of work has been done along this line but so far no poison has been found which is effective and economical on a plantation scale. The Station is experimenting with certain poisons so that if they are efficient they will give relief to the worst spots even if they be not applicable to large areas.

Biological Control

Having been successful with the biological control of insects in the Islands it is natural to consider such a method for controlling nematodes. Unfortunately our knowledge of nematodes is not so great as it is of insects or perhaps we could handle the problem in a similar manner. Cobb and other workers have shown that certain nematodes are predaceous and feed upon other nematodes. So far as we know at present we have four species of a predaceous genus (*Mononchus*) in the Islands, but the only one we have found in our present work is *Mononchus brachyuris,* and that appears to be confined to damp soil or soil

Fig. 13. A predacious nematode. The front view of head is correct; the body is more imaginary, but nearly correct. (After Cobb.)

that has been heavily treated with organic fertilizer. In such localities where this nematode is found other nematodes are not numerous. Whether other species could be found elsewhere which would live in our other types of soil is a point worth considering. There is a record of a fungus-killing nematode (*Arthrobolys oligospora*) which should be investigated. What other soil-inhabiting animals or plants attack nematodes we do not know.

The above is a very short and partial presentation of the nematode problem in Hawaii. It is of great interest to the agriculturist and the biologist, but from

Fig. 14. Another predacious nematode. (After Cobb.)

its complex nature difficult to explain briefly. If the reader should find it uninteresting it is not on account of the subject but because the writers have failed to present the problem clearly.

The Soil Fauna of Hawaiian Cane Fields

By R. H. Van Zwaluwenburg

This article aims to point out the various kinds of animals found in Hawaiian cane soils, their numbers, and their relation to the cane plant. It is preliminary in character, for the work is still going on. Discussion is confined to such forms as can be seen with hand-lens or naked eye; in other words, to what may be termed the "macrofauna," and does not include the field of nematode worms.

General Observations

The bulk of the subterranean animal life is contained in the upper 9 inches of soil, although individuals are found below that level whenever physical con-

ditions are favorable. The top 9 inches also contain over 50 per cent of the mass of cane roots.

The main factors affecting animal abundance in soil are: (1) ample food supply, which may consist of growing plant-tissues; decaying organic matter or, for parasitic and predaceous forms, animal food; and (2) favorable moisture content. An irrigation will cause the majority of the insect inhabitants of the soil to move upward from the lower levels, but the position of the centipedes, mites, etc., seems to be but little affected by additions of moisture. Myriapods and insects alike increase in numbers during the rainier months of the year.

The most numerous groups of animal life in the soil are: (1) myriapods, including centipedes and millipedes; (2) insects; and (3) arachnids, including the spiders and mites. Groups occurring in much fewer numbers are the larger worms, the crustacea (including sowbugs), and the molluscs, which include the snails.

The economic importance of this soil fauna, aside from such definitely injurious insects as the *Anomala* beetle, has yet to be determined, and its possible complicity in growth failure (root rot, Lahaina disease) makes its study of value. The evidence against some of the commoner forms will be discussed below. Not all the soil inhabitants are injurious; the common earthworm (unfortunately rare in the irrigated plantations) does an enormous amount of good in slowly bringing up soil from the lower levels, and in breaking down organic matter. Likewise, a very common millipede is no doubt of benefit in breaking down old roots.

Our results are divided for convenience according to three types of land, as follows:

A. Clean fallow; land which had no crop, and few or no old cane roots.

B. Root-fallow; land containing old cane stubble and many roots, but no growing crop.

C. Growing-cane land; either plant or ratoon. In the latter case it is partly root-fallow in nature due to the decaying roots of the previous crops.

Comparative Abundance and Vertical Distribution

Growing-cane land has nearly four times as many animal inhabitants as bare-fallow, and over one and one-half times more than root-fallow land (see Fig. 1). The numerical ratio is as follows: clean-fallow, 10; root-fallow, 23; growing-cane land, 37. The insects outnumber all other groups in each type of land, although in root-fallow the myriapods are nearly as numerous as the insects, their increased numbers here being explained by the preference of millipedes for decaying roots (see Fig 2).

In clean-fallow the bulk of the animal life is normally between 3 and 7 inches; in root-fallow between 5 and 9 inches; and in growing-cane land between 1 and 5 inches, which is the depth at which the mass of growing roots is greatest (see Fig. 3).

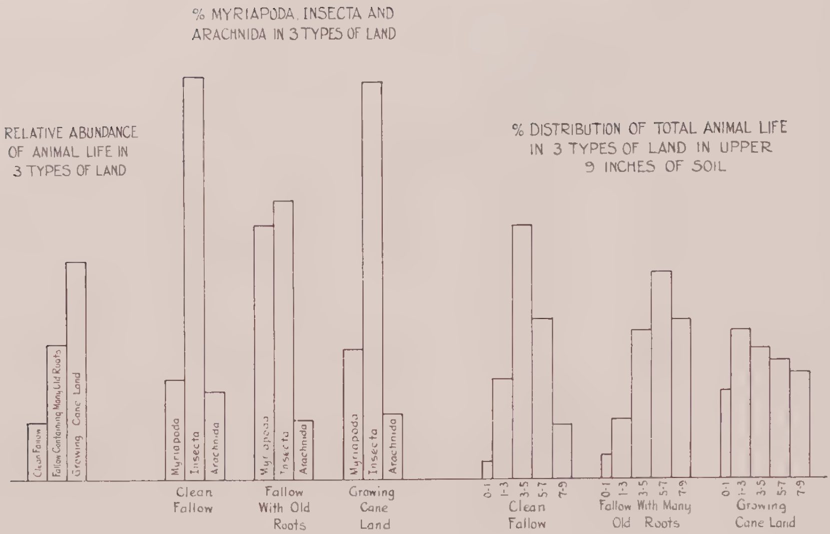


Fig. 1. Fig. 2. Fig. 3.

The groups of animal life are most numerous at the following depths in the three types of land:

Myriapods:

Clean-fallow, most numerous at 3-5 inches.
Root-fallow, most numerous at 7-9 inches.
Growing-cane, most numerous at 5-7 inches.

Insects:

Clean-fallow, most numerous at 3-5 inches.
Root-fallow, most numerous at 3-5 inches.
Growing-cane, most numerous at 1-3 inches.

The arachnids are very evenly distributed to 9 inches in all three types of land.

Injury to Cane Roots

In most cases the injury to the roots by the soil animals takes the form of a round pit, varying in diameter with the size of the attacking species. Almost all such injury is confined to the cortex and seldom penetrates into the stele. A favorite area of attack is the one-half to one inch of root free from root hairs immediately behind the growing tip. Not infrequently the root-cap itself is pitted.

Several of the animals commonly found in cane soils have injured cane roots under laboratory conditions, and probably do so in the field to some extent. Growth failure has been observed where no injury by the macrofauna was visible, and on the other hand, vigorous stools have been seen which had an enormous amount of pitting on the roots. The possibility of pathogenic fungi or bacteria gaining entrance through cortex wounds is recognized, and is the subject of experiments now under way. Another possibility is that under favorable conditions a cane stool can survive an amount of mechanical injury from soil animals which in the presence of unfavorable physical or chemical conditions would tip the balance sufficiently to result in growth failure.

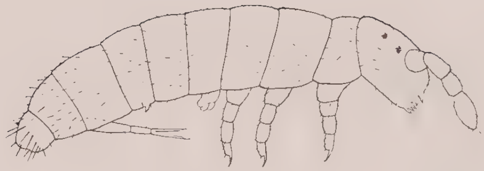


Fig. 4. Collembolous insect exceedingly numerous in all types of soil. It has biting mouth-parts, and under laboratory conditions makes pits in the tender parts of cane roots. X 100.

In growing-cane land the potentially injurious forms average about 66 per cent of the total animal life present, exclusive of the nematodes. The following have fed repeatedly upon freshly cut cane roots in the laboratory:

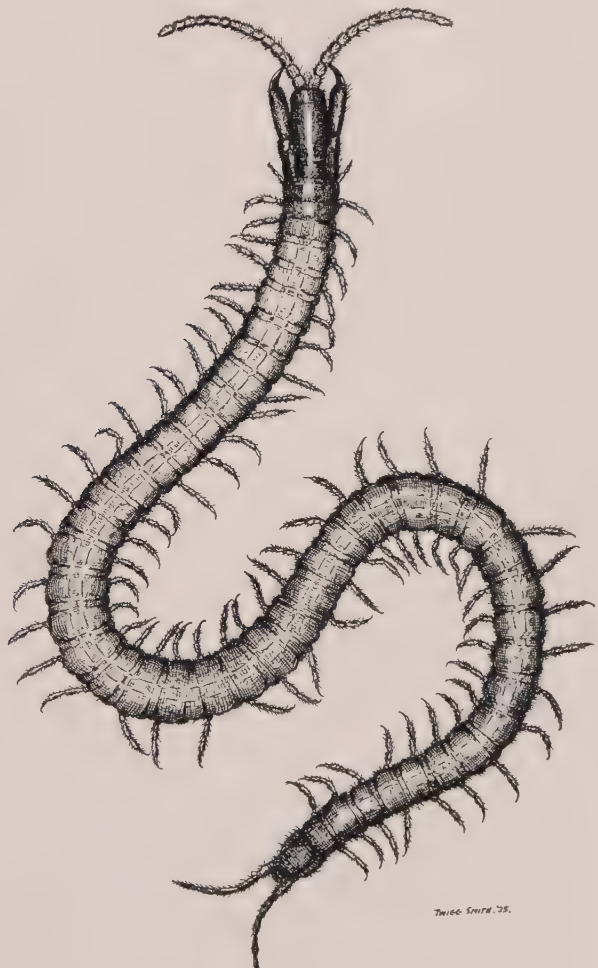


Fig. 5. *Mecistocephalus maxillaris.* A common centipede which forms pits in healthy root tissue. X 8.

1. *Collembolous insect* (Fig. 4). An unidentified insect averaging about 1/25 of an inch long, related to the snow-flea of the mainland. It makes round pits, very small in diameter and comparatively shallow. Suspicion points most strongly to this insect as a possible factor in growth failure, due to its widespread and abundant occurrence. It forms about 55 per cent of the total animal life in soil in which cane is growing. Part of its food is probably decaying vegetable tissue since it breeds abundantly in land containing old cane roots.

Fig. 6. A common millipede which can make pits but probably prefers dead roots to living ones. X 35.

2. *Centipedes* (Fig. 5). Two species of centipedes varying in size from ½ to 1¼ inches form comparatively large, deep pits in the roots. One of these, *Mecistocephalus maxillaris,* was first shown by C. E. Pemberton (see *Planters' Record,* January, 1925) to produce these pits, and due to its abundance at Honokaa, it was early suspected as a possible factor in growth failure on that plantation. This species when adult has 48 pairs of ambulatory legs. The other centipede has 36 pairs of ambulatory legs and causes pitting indistinguishable from that of *M. maxillaris.* Both species together form about 5 per cent of the total macrofauna of growing-cane land, and have been found on all of the cane-growing islands.

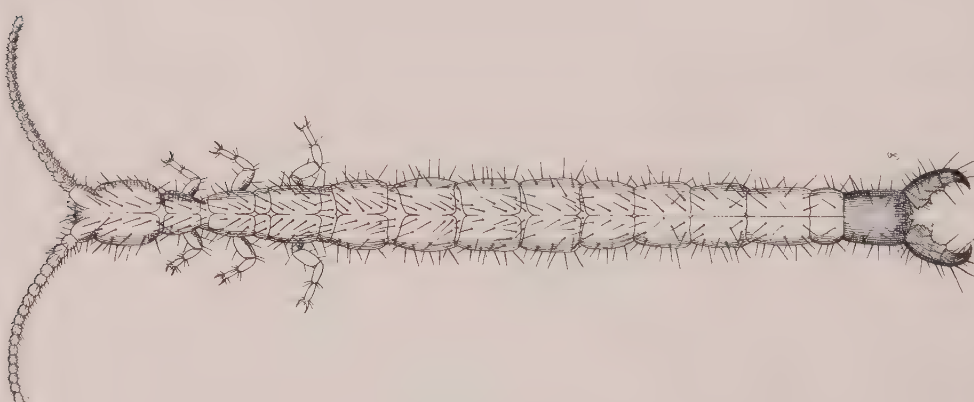


Fig. 7. *Japyx sp.* An insect which in the laboratory has made pits in healthy cane roots. X 50.

3. *Millipedes* (Fig. 6). A small white millipede about ¼ of an inch long is sometimes very abundant, especially in land having many old roots. Its principal food is probably decaying roots. On fresh roots in the laboratory it sometimes makes rather wide pits, but generally rasps off the cortex tissue. It constitutes about 4 per cent of the fauna in growing-cane land.

4. *Japyx* sp. (Fig. 7). This is a white insect about ⅛ of an inch long with a chitinized forcep-like organ at the end of the body. Its injury to roots in the laboratory takes the form of irregular shallow pits. It is seldom common, and constitutes less than 1 per cent of the fauna of growing-cane land:

5. *Caecilioides baldwini.* This is a very small snail, similar to a species which is said to be involved in growth failure in Louisiana. It forms a clean round pit on fresh roots in the laboratory. We have not seen it in the field in enough numbers to account for growth failure. It is so rare that numbers sufficient for experimental purposes were obtained with great difficulty, and then most abundantly in abandoned pineapple fields under rotting leaf-sheaths.

Exotic Trees in Hawaii

By H. L. Lyon

It appears that young Hawaiian lavas make a suitable substratum on which the native plants will grow luxuriantly, providing they are supplied with the necessary moisture. When these same lavas disintegrate and decay into finely divided materials, however, the residual soils invariably contain, as products of decomposition, soluble, mineral compounds which are poisonous to the native plants, and consequently on old soils these plants are always delicate and prone to die off upon the slightest interference from man or the foreign animals and plants which he has introduced.

The creation of new forests to replace our disappearing native forests is obviously one of the most vital problems confronting the Territory. To solve this problem, we have got to find trees that will grow on our watersheds despite the adverse soil conditions existing thereon. The only practical method of procedure is to determine by experiments the various species of trees, shrubs, etc., that will grow even though these poisons are present in the soil. This was the first step in forestry work undertaken by the department of botany and forestry of this Experiment Station upon its inception.

We have introduced exotic trees from many parts of the tropics and subtropics and planted them in as many localities as possible in the Islands to determine their reactions to the existing conditions of soil and climate. As was to be expected, a very large percentage of the trees planted in our experiments failed to make a normal, healthy growth. Some succeed in one locality but fail in others, but a few seem to thrive in every locality in which they are planted. It is trees of this latter class that we shall recommend for general use in our forest plantings. While our experiments have really been in progress but six years, still we have already obtained sufficient data on certain species of trees to warrant an opinion on their merits as components of the forests which we wish to build on our watersheds.

Fig. 1. *Albizzia moluccana.* This photograph was taken in January, 1922. At that time, the tree had been in the ground just one year. It was a seedling about three feet tall when planted out.

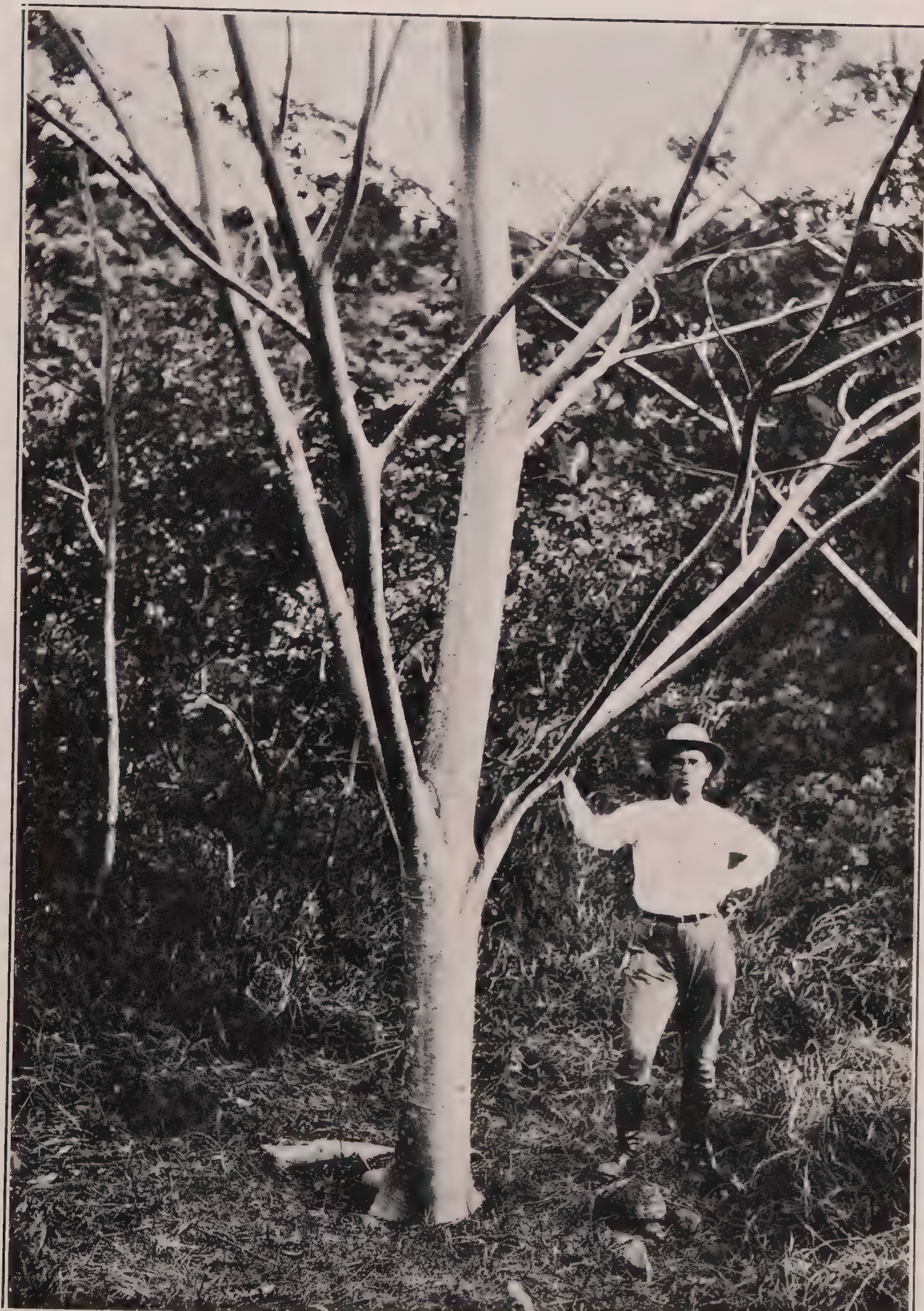


Fig. 2. *Albizzia moluccana.* The tree shown in Fig. 1 as it appeared in February, 1926, when six years old from seed. It should be a profitable fuel crop to plant on lands otherwise unproductive.

In a series of articles appearing in *The Record* we shall describe and illustrate some of the exotic trees which are showing up well in our various arboretums and forest plantings.

Albizzia moluccana: This leguminous tree from the Malayan region has, on the average, made more rapid growth than any other tree in our cultures. It is said to prefer a heavy soil in a moist situation and to thrive up to 4000 feet elevation in Ceylon. It does not cast a heavy shade, hence fosters a vigorous undergrowth. Some authorities report that it is a short-lived tree, but reproduces freely, always maintaining a good stand on the land. Troup, in his *Silviculture of Indian Trees,* says of this species:

> A very large fast-growing Malayan tree with light foliage and a straight, clean, smooth, grey bole, branching high up. It is largely grown in Ceylon and Java as a shade to coffee, and is worth cultivating as a quick-growing shade tree for other crops requiring light shade, as it is said to possess soil-improving properties. It has recently been grown on land cleared for tea in Assam, where in the Towkok garden, Sonari, Sibsgar district, trees four years from seed were reported in 1913 to have grown 46 feet in height with a girth of 2 feet, 9 inches at 3 feet from ground-level. Plantations of this tree have recently been formed in the Andamans, where it grows well even in exposed situations and is not affected by wind. Plants from seed sown in December, 1912, attained by 1916 a height of 30 to 35 feet and a girth of 1½ to 2 feet; those on the soil of cleared evergreen forest attained in the same time a height of 40 to 45 feet and a girth of 2-3 feet at 3 feet from ground-level. A tree in the Royal Botanic Gardens, Peradeniya, Ceylon, eleven years old, was 125 feet high and nearly 11 feet in girth at 2 feet from the ground. In Ceylon, the pods ripen in May-June; the seeds are small, about 1,200 weighing 1 oz. The wood is soft and light, and suitable for tea-boxes and planking. Owing to its rapid growth, it should be worth planting for this purpose in suitable localities.

This tree is doing remarkably well in the Manoa arboretum, as may be seen from the photographs reproduced herewith. It has also made very good growth in our plantings in the Halawa-Niulii forest area around 2000 feet elevation. The wood is very brittle and trees planted in exposed situations are very apt to be broken by the wind. If planted in groves, however, they weather heavy storms with the loss of branches only and these are soon replaced by new growths. It is quite evident that this is going to be a very useful tree in our forest plantings below 3000 feet elevation, and will enable us to quickly cover denuded areas with vegetation having considerable vertical depth. Unfortunately, the local-grown trees are as yet producing but few seeds and consequently we must secure most of our seed from abroad. This is proving a rather difficult matter to accomplish.

A Review of Soil Investigations Pertaining to Growth Failure of Sugar Cane*

By W. T. McGeorge

The most of our work on this plant failure problem has been along two rather definite lines: one covering the acid soils and the other the more alkaline soils on the irrigated plantations. The acid soil work has been principally upon the toxicity of aluminum salts with a small amount of work on the manganese and iron salts. The basis for this aluminum work is that carried on in the states in which it has very definitely been tied up with corn root rot; in Austria where it has been tied up with sugar beet root rot, and also in India where it has been found to be associated with the wilt of cotton. When we started our investigation there had been no definite attempt made to classify soils in which we might expect to find aluminum toxicity; so the first work that we did was to select a series of soils covering the range found here in the Islands and to determine which of these soil types contained soluble forms of aluminum. This series ranged from a pH of 4 to a little above 8 and we found that all the soils more acid than that represented by a pH of 5.8 contained soluble forms of aluminum and were classified as possibly being toxic. Since this work was completed there has been a paper published from the University of Wisconsin covering a similar study which has confirmed our work, but also has gone into the soil study more extensively. They studied the solubility of aluminum salts from an acidity of pH 3.5 to an alkalinity of pH 10, and found the lowest solubility of aluminum at pH 5.7 which is very close to our 5.8. On the other hand, they found that the solubility of aluminum increases with alkalinity, so that when you get up to a pH of 8.5 to 9 you have very large amounts of aluminum coming into the solution as alkaline salts. We have been figuring on taking up this phase of the work for some time but have never felt that there was any possibility of toxic aluminum in the alkaline soils, because all our alkaline soils are very high in lime and calcium aluminate is a very insoluble compound. So we never felt that we could anticipate any toxic aluminum in our alkaline soils, but that is one phase of the work that we intended to go on with. This work at Wisconsin was carried on in salt solutions so that the figures which they give out do not necessarily mean that alkaline soils would contain soluble aluminum compounds. There is another phase of our work on the acid soils that seems to me to be very important. In our highly organic soils, such as those from Olaa down the Hamakua Coast to Pacific Sugar Mill, the acidity is not so high as it is in our red clay soils but the toxicity seems to be much more active there. The soluble amounts are not so high, but the availability seems to be very high and I think that is one reason why we find considerable amounts of toxicity in some of those less acid Hamakua soils.

* Presented at an Experiment Station staff meeting January, 1926.

After this soil work our next step was to determine whether aluminum salts were toxic towards sugar cane. In this part of the work I think we proved beyond question that they are toxic. There have been several criticisms of the methods used for determining the toxicity of aluminum salts. One of these is that some investigations have failed to take account of the fact that wherever you have aluminum salts in solution you necessarily also have acidity or hydrogen ions. On this basis they contend that toxicity may be due in part to acidity. We carried on experiments considering this criticism and found the acidity itself was not toxic toward sugar cane, but in the presence of aluminum salts there was an unquestionable toxicity and we obtained this toxicity in concentrations of only 10 parts per million, which amounts are often found in our soils here. There has also been some criticism that aluminum toxicity is nothing more than a phosphate or other plant food deficiency. To answer this we ran some experiments in which we left off phosphate entirely; we also left off lime and potash and on growing the plants in these cultures there was no stunting in growth from leaving off these plant foods. The deficiency of nitrogen was the only one that stunted the plant. Along with this series the aluminum salts showed very strong toxicity even in the presence of these nutrients so that we feel as far as we have gone that there is no question but what there is a direct toxic action of aluminum towards sugar cane.

Then, our next step was to carry on some pot experiments. For this purpose we selected two distinctly different acid Island types, the acid clay and the acid organic soil and were able to show rather definitely that these soils respond slightly to lime and very remarkably to heavy phosphate and potash applications. Both of these treatments have been considered in the States as being corrective methods of reclaiming acid soils. In the early work in the States lime and phosphate were extensively used in building up these acid soils, but some later work has shown that certain very well defined cases of corn root rot have responded only to potash applications and that phosphate and lime neither singly nor together would reclaim these areas. So I think there is a great deal to be learned even yet about the nature of aluminum toxicity. One of the principal conditions found to be associated with this toxicity is the accumulation of these metals at certain vital points in the plant. Dr. Hoffer has associated this with the failure of corn in the Middle West. We have applied his tests quite extensively with many positive results, indicating that on the whole our two problems are very closely related. He has found that potash seems to prevent these accumulations of aluminum and iron in the corn stalk. We carried out a test of this nature at Honokaa in which we compared the stalks of cane treated with potash applications and the untreated. Both the qualitative and quantitative determinations of iron and aluminum showed that these elements had been greatly reduced by the potash in the internodes and the nodal joints where the accumulations seem to take place.

There is still one phase of our soil work that I think should be more definitely studied, and that is the fact that we do not seem to get immediate response to lime. I think that response will come after a period of years and I do not believe a permanent reclaiming of these acid soils will ever be brought about without the

application of lime along with these potash and phosphate treatments which seem to give more immediate response. We find a similar relation in alkaline or neutral soils in some of our experiments where we have added aluminum salts to try and produce aluminum toxicity. On the Station soils we have failed to reproduce it with reasonable amounts of aluminum salts, even though we get the acidity, showing that there are certain factors associated with aluminum toxicity in acid soils which are not formed immediately on making fertile soils acid. In taking red clay soils such as we have in the upper fields of the Oahu Sugar Company it is very easy to reproduce aluminum toxicity in these soils, and I think it is because they are low in lime, phosphate and potash and soils which do not contain very large reserve amounts of these necessary elements. Another very important thing is that when we reach the toxic acidity in these Oahu Sugar Company soils we find that the solubility of lime has been increased about four or five times. This seems to indicate how rapidly lime would be leached from acid soils and how quickly they would soon reach the stage where aluminum would begin to function as a replaceable base and become toxic. That is, where the soil contains appreciable amounts of lime this element will play the principal role of replaceable base; but as soon as aluminum or iron commences to act as replaceable bases there results the soluble salts, which are toxic. I think this covers the aluminum work pretty well.

The work which we have done on the irrigated or alkaline soils has been principally on the effect of saline accumulations from irrigation water. This work is by no means a new subject. I think Maxwell, Eckart, Peck and Burgess all devoted some time to it. Burgess confined his work almost entirely to black alkali. We began work on this phase of the problem after the soil work which has just been spoken of, showing that we could only expect aluminum toxicity in acid soils. At this time Dr. Lyon had a small experiment down in Field 14 at Ewa where he had put in some Lahaina cane and it was making practically no growth at all, yet was surrounded by perfectly good H 109 cane. The first thing we did was to remove the soil solution from this soil and make an analysis of it. The analysis of the soil solution showed a very high concentration of soluble salts from the irrigation water. We then went to quite a number of areas on this island where Lahaina was still growing or had failed and found that there was a higher concentration of soluble salts in the soil solution in the fields in which Lahaina had failed. The next thing we did was to take this soil from Field 14 at Ewa and subject it to a series of leachings before planting to Lahaina cane. We found that the growth of Lahaina was materially aided by leaching out these soluble salts. Then by analyses of the plants we were able to show that there had also been a material change in the composition of the Lahaina. That is, normally the plant contains large amounts of sodium in the roots and small amounts of potash, while in the tops the potash is very high and the sodium very low. We found that this ratio was materially changed by these high concentrations of soluble material and that by leaching and lowering the concentration in the soil solution we were able to improve the growth of Lahaina and at the same time the analysis of the plants showed an approach toward normal composition. The next phase of our work was to carry out an extensive series of water plant cul-

tures in which we compared the growth of H 109 with Lahaina. The analysis of this soil solution from Field 14 at Ewa showed that the principal salts present in the soil are the calcium, magnesium and sodium chlorides and the sulphates of these same elements. So we made up an extensive series of cultures, varying in concentration using these salts separately and while there was some difference between the effect on H 109 and Lahaina there was not sufficient difference to account for the difference found in the field. On the other hand, when we combined these chlorides in the same ratio in which they were present in the soil solution we were able to show very definitely that the combined chlorides were far more toxic toward Lahaina than H 109. I think this fact shows very definitely why H 109 grows better on many of our irrigated fields than Lahaina does. It is very easy to explain the effect of these conditions on plant growth because when the plant root absorbs a salt it does not absorb the salt as a whole, but only the ions. Also when it absorbs a soluble material it cannot return this to the soil solution again by diffusion. That is to say, the plant root only gives off water and carbon dioxide but may absorb any ion of a salt present in the soil solution. On the other hand, many plants exercise a selective action in absorbing ions from the soil solution, which property gives them greater resistance. In fact, it is very easy to find several explanations which would account for the disturbance which seems to follow the conditions mentioned. I think that is about all I have to say on these points.

Discussion

Agee: You spoke of the question of liming acid soils. At this time some of the plantations on Hawaii are spending large amounts for lime and other plantations nearby are spending nothing. The feeling is that if lime is a good thing they should all put it on, or if nothing is to be gained from its application that the expense now being incurred by some plantations could be saved. What would your recommendations be in such a case?

McGeorge: The question in my mind is, what will be the condition of those fields fifty years from now? The Honokaa lands, for example, are very deficient in available lime. Under those conditions you find aluminum salts acting as replaceable bases. I realize, and I have admitted right along, that experimental evidence is all against the economic value of lime on those fields; but at the same time there is no question but what lime will bring about the conditions which operate against the activity of aluminum salts and its use is theoretically sound. It is just a question of what they will be fifty years from now. There are several cases where they had evidence of a better growth of Lahaina after the application of lime; for instance, the work of Hartman, chemist at Onomea Sugar Company, under the management of Mr. Goodale. Then there is Mr. Lidgate's experiment at the Hamakua Mill, but outside of a few mauka fields on Kauai I have not seen any indication that there is any immediate economical return from liming.

Agee: It certainly makes it a very difficult question to have this difference between theory and actual field test.

Lee: Don't your pot experiments show a response from liming, Mr. McGeorge?

McGeorge: Yes. Our experiments on Honokaa soil were on soil from Field E.

Lee: I was wondering if a more intimate mixture of lime such as in the pots might give a quicker result in field test.

McGeorge: We got some better results, but in the field experiments, thus far I can see no notable response. It is a queer thing about this aluminum toxicity problem. I do not believe that it is or will be a factor in the good fertile soils. Most of our acid soils are deficient in lime, phosphate and potash, which deficiencies seem to operate to make aluminum more toxic.

There is still the possibility of ferrous iron. I think that this may be one of the factors at Olaa. Most Olaa soils are not acid enough to contain aluminum salts in soluble forms but they contain quite a bit of ferrous iron and in a number of stalks which I have examined I always got a good strong test for these accumulations of iron. Then again we have a number of areas at Waimanalo where there seems to be a growth failure of some sort. I found a very interesting relationship there in Field 23. There is one low spot which is just alongside of a knoll and on this knoll the plants are entirely normal. I took a stalk from this knoll and one from down in the lower spot where the growth failure was so bad and drainage poor and made a test for these accumulations. The good cane from the knoll where the drainage was good gave a negative test and the cane in the low spot where the growth failure was very pronounced gave a very strong test. Now, according to what Mr. Beveridge told Mr. Stewart those areas began to pick up after the cool weather and the rains came on. The last time I was there I noticed very distinctly that in the drainage ditches running through the fields the water was seeping out and the ditches were lined with a coating of oxidized iron. The iron was being precipitated out of these leachings showing very distinctly that one of the changes taking place in the soil is the leaching away of the ferrous iron. Whether this is the cause of the poor growth I do not know, but it is associated with the conditions there. That is one phase of a problem which we are preparing to take up, a study of the oxidation and reduction in the soils to bring about a better oxidizing environment in some of these low areas. I have grown some cane shoots in a solution containing colloidal aluminum hydroxide to see if these colloidal materials, which you are sure to have in a maximum amount in a poorly drained soil, would have any effect on the root growth and I found that the roots were greatly stunted by coming in contact with the colloids. I think it was the coating of colloidal material on the roots which had prevented proper respiration. After the plant had grown for a month or so in this solution I transferred it to tap water and the roots are growing along serenely. It was just a temporary effect and not a toxic effect.

Newcombe: Do you know whether the same roots started up growth that were already there?

McGeorge: Yes, the principal difference was in the secondary roots. Yes, there were new roots forming there, too. The roots were not dead, they were simply not growing.

Agee: Has there been any indication of soil trouble in connection with the lower land of the Oahu Sugar Company which could have affected and accounted for the failure of Lahaina?

McGeorge: The only thing was that the areas which Mr. Paris pointed out to me at Waipio were high in saline material but not sufficiently high at the time I sampled the soils to account for any growth failure. They were higher than where I found the Lahaina still growing well. The only reason I have to suspect high salt to have been associated with Lahaina failure at Waipio is that when those Lahaina experiments were put out at Waipio along about 1913, a very extensive set of experiments, they had a heavy rain, about 10 inches of rain in a few days, and the disease failed to appear in any of this planting. The soil would get a very extensive leaching in 10 inches of rain. Down in the Peninsula fields of the Oahu Sugar Company the saline accumulation is very high and the soils are very sticky, a character which is usually noted in a soil subjected to saline irrigation for a period of years. That is another point: in our pot experiments where we add large amounts of salts we probably reproduce the concentration of the salt but we do not reproduce the poor physical condition that we get from years of saline irrigation.

Agee: How about upper lands of the Oahu Sugar Company?

McGeorge: I have no theory at all about those fields. There is only one characteristic that I know of, that is, they are all low in phosphate and the poor growth of Lahaina there may have been due to deficiencies.

Agee: Phosphate starvation may have been the cause of their trouble.

McGeorge: Did Lahaina actually die there or was it just stunted?

Agee: I do not think that it actually died any place. In general the cane would be in great distress over the winter, and the second summer it would recuperate to some extent and would usually make four or five or six tons of sugar even in fields that had looked quite poor.

McGeorge: In one of Dr. Lyon's reports on some observations at Ewa he mentioned in his letter that the plant looked as though it were suffering from drought, even though there seemed to be plenty of moisture in the soil. That is a condition brought about by high concentration in the soil solution. The plant depends on the process of osmosis to obtain its salts and if the concentration in the soil solution is greater than that in the root cells you are going to have moisture coming out of the plant instead of going in. So that plant will wilt even though the soil is well saturated with water. Do you remember that case, Dr. Lyon?

Lyon: I recall the conditions.

McGeorge: Osmosis would be, I should think, the only way to explain that condition.

Lyon: In some of the swamps in Northern Minnesota you will find considerable deposits of iron in soil that is under the water. I am not positive but as I remember it, it is mostly ferric iron. Have you noted that condition in the swamps, Dr. Newcombe?

Newcombe: Yes, it is called bog iron.

McGeorge: At Waimanalo in Field 26 below the mill, which is one of those poorly drained sort of bluish soils, Mr. Chalmers, the manager, says that some-

times during very wet weather there will be standing water on that field and that water will be covered by a film of iron.

Lyon: That condition is very common in the forests on Maui. Regarding this iron in swamps: when I was in the Federated Malay States I had an opportunity to get into a swamp in which I noticed the same conditions. What would be the conditions that would permit that iron to remain as ferric iron?

McGeorge: I should think it would be a lack of sufficient conditions to hydrolize the iron and precipitate it, or possibly an acidity high enough to keep the iron in solution. I have seen the same thing in well waters coming from great depths. They will be perfectly clear, but on standing twelve to twenty-four hours will show a large precipitate of iron. I think it may be the lack of carbon dioxide at that depth.

Lyon: This is not carbonate; it is the oxide. It is always well down and it results through precipitation from a solution of ferrous iron, and you will find deposits of considerable depth in some of the bogs. There are certain bacteria that oxidize ferrous iron to ferric iron.

McGeorge: Soils contain deferrifying and ferrifying bacteria. At Olaa there is a great deal of ferrous iron in the soil. But in most of their best soils it is not permitted to accumulate as in some of the heavy soils at Waimanalo. Under those conditions it would be drained away, but as you get up in the Mountain View section there are some very poorly drained soils and at the same time the growth is very stunted. In most of the Olaa fields the water does not accumulate and I think the ferrous iron is leached away rapidly. Olaa conditions are very humid, under which conditions you do not get sufficient oxygen to form the ferric iron as has been found in drier island districts. It has not had an opportunity to reach the ferric form.

Lyon: In the soils beyond Kailua, Maui, we found that ferrous iron constituted 20 per cent by weight of the soluble materials. Those samples included only the upper 6 inches of soil. The soil is at all times saturated with water right up to the surface. You dig a hole and it fills right up with water. Is it not possible that we might use these ferrifying bacteria in some of our soils here? I think it is worth investigating. On Maui in the slow running streams draining down from these swamps there is an abundance of ferric iron but the soil solution as we found it is all charged with ferrous iron.

McGeorge: At Olaa we went to Mountain View section and one other section near Keeau Store and obtained samples of soil. They were too wet to run a test for ferric iron, but we ran a test for curiosity and it was negative. So then we put the samples in the oven over night and obtained a wonderful test for ferric iron. I assumed these would be good areas for an experiment, but after I got back to Honolulu and made a more careful test I found it was all ferrous iron and the soil was not sufficiently acid to have ferric iron present.

Lyon: It is very difficult to determine the amount of ferrous iron.

McGeorge: Yes, as soon as it hits the air it oxidizes. If the soils were inoculated where would the bacteria get their oxygen to do the work?

Lyon: They would have to work near the top, but they would go down as the oxidation of the ferrous iron proceeds and they would have to work at a

greater and greater depth. They work suspended in the solution and at different depths depending on the penetration of air into the solution. I suggested that we investigate these bacteria a number of years ago, but it has always been frowned upon as a dangerous proceeding because we might bring in some other organisms.

Agee: Why not bring it in a culture medium?

Lyon: They are very hard to culture. They have to be given very peculiar conditions.

Agee: Didn't you or Stewart conduct some work in which you attempted to study a soil which had been in cultivation for 20 years in comparison with an adjoining area which had never been cultivated at Ewa? What were the essential differences?

McGeorge: I ran the total carbons to see if the organic matter had been depleted and there was no change in the amount of organic matter in the cultivated soil. Stewart, I think, examined those samples for alkaline accumulations, that is black alkali, and I think he said that he found there was no tendency toward an alkalinity in any of the samples that he examined.

Agee: Do you remember any differences in organic matter?

McGeorge: We found no differences whatsoever. That was, I thought, explained by the work which you did. You weighed some cane roots and found 4 or 5 tons of roots to a 45-ton crop of cane.

Agee: I think most people completely overlook this when they talk about the necessity of applying organic manures. In a heavy root system they leave organic matter in the soil and organic nitrogen that was imported in chemical form.

Lyon: The roots are already well distributed and incorporated in the soil, too. In speaking of the upper fields of Oahu, in the past have you had rains heavy enough to leach these soils? There are probably lots of soils on this island that have never been leached.

McGeorge: I saw a figure the other day, I don't know how accurate it is, but it mentioned that a 15 months crop of cane required 216 inches a year. Now when you compare that with the rainfall in the cane growing districts there are few that are as heavy, so that you are bound to have these accumulations where your water requirement and evaporation greatly exceed the actual rainfall.

Muir: Where were those figures taken from?

McGeorge: Maxwell's Bulletin on Irrigation in Hawaii. We found one soil at Ewa which contained 50,000 parts per million total solids.

Agee: How much is sea water?

McGeorge: Thirty-five thousand. That is 15,000 more than sea water. And the H 109 cane did not seem to be injured by it. We find that this saline material increases during the summer and then decreases very materially during the winter season when the rains come on. You can get very definite measurements throughout the year on the changes in areas.

The Distribution of the Roots of Young D 1135 Plant Cane in the Soil

By H. Atherton Lee

In the studies of Lahaina disease, or growth failure, it has become evident that a knowledge of the root systems of normal cane is essential before conclusions can be drawn as to the relationship of root injuries to such growth failure. With this in view root-study boxes have been built which permit the washing away of the soil from the roots, and the roots when freed from the soil are held in position by a network of wires and so permit an examination of the underground system.

The first results obtained from these root-study boxes are apparently equally as interesting from an agricultural standpoint as they are in relation to root injuries. The following table shows the distribution of roots at different depths in the soil. Previous attempts at determining the distribution of roots have been by linear measurement which, because of the great numbers and branching character of the roots, could not be exact. For this reason in these studies the weight of roots was substituted for linear measurement and would seem to be a much better index of the presence of roots in a given area of soil.

TABLE I

Showing the Distribution of Roots of D 1135 Plant Cane 4½ to 5½ Months Old at Different Levels of the Soil [1]

	Topmost 8 Inches		8 to 16 Inches in Depth		16 to 22 Inches in Depth		22 to 30 Inches in Depth		Age of Plants
Plant No.	Weight Grams	Per cent	Weight Grams	Per cent	Weight Grams	Per cent	Weight Grams	Per cent	
1	71.4	58.5	30.6	25.0	6.9	5.6	13.1	10.7	145 Days
2	17.0	55.0	6.0	19.0	3.1	9.8	5.4	17.1	145 Days
3	133.7	68.8	25.8	13.2	15.3	7.3	19.5	10.0	161 Days
4	55.4	56.7	26.3	26.9	8.3	8.4	7.7	7.8	161 Days
5	96.8	64.1	31.9	21.1	10.6	7.0	11.5	7.6	168 Days
6	79.0	70.1	14.9	13.2	7.7	6.9	10.9	9.7	168 Days
Totals and averages....	453.3	63.9	135.5	19.1	51.9	7.3	68.1	9.6	

From the results shown in the foregoing table one observes that, averaging all plants, 63.9 per cent of all roots occurred in the top 8 inches of soil. In the next level, between 8 and 16 inches in depth, 19.1 per cent of the roots occurred,

[1] The root-study boxes in which these plants were grown were partially lowered into the soil to present natural conditions as nearly as possible. The cane was irrigated at no regular intervals but water was added from time to time to keep the soil moisture as nearly at optimum as possible. All plants received uniform applications of nitrate of soda but no phosphoric acid nor potash.

or a total for the top 16 inches of soil of 83 per cent. In the next level at the depth of 16 to 22 inches, 7.3 per cent of the total roots occurred or, taking the upper 22 inches as a whole, 90.3 per cent of the roots occurred in this upper 22 inches of soil.

The table shows a slightly higher percentage of roots in the bottom-most layer of 8 inches. This is because a few of the roots were beginning to reach the bottoms of the boxes and extend laterally.

The roots of the first two plants were examined when they were 145 days old; the next two plants were examined when 161 days old, and the last two when 168 days old. It might be argued that with age the percentage of roots at the lower levels would increase, but a careful examination of the figures shows no tendency in this direction and apparently, although the roots go more deeply with age, there is a corresponding increase of the surface roots at the same time.

In these studies two types of soil were used. Plants 1, 3 and 5 were grown in soil from the pathology plot, which has been notably free from any types of Lahaina disease, or growth failure. Plants 2, 4 and 6 were grown in soil from the upper part of Field 31 at Honokaa where D 1135 in small areas has suffered from soluble aluminum injury. The pathology plot soil is a heavy, loamy soil of a compact nature, while the Honokaa soil was much more loose and friable. The photograph produced shows the poor growth of the D 1135 in the soil from Honokaa with unusually active aluminum compounds, as compared with the growth in Makiki soil. A study of the roots in the Honokaa soil showed that in this five-month-old cane there was no abnormal rotting of roots; the principal difference was that the plants in the aluminum soil did not produce the quantities of roots which the plants were able to do in the Makiki soil. The differences in the amounts of roots in the two different soils are also shown in Table I. Plant No. 1 yielded 122 grams of roots, as compared to 31.5 grams of roots in Plant No. 2. Plant No. 3 yielded 194 grams of roots, as compared to 97.7 grams of roots for Plant No. 4. Plant No. 5 yielded 150 grams, as compared with 112 grams for Plant No. 6.

It is interesting to observe that the ratio of deep roots to surface roots was, however, practically the same in the two distinct types of soil used, the loose, friable Honokaa soil as compared to the heavier more compact Makiki soil. This is shown in the brief table following:

TABLE II

Showing the Similarity in the Distribution of the Roots of Five Months Old Plant D 1135 in Loose Honokaa Soil as Compared to More Compact Makiki Soil

Depth of soil	Roots of all plants averaged Percentage	Roots of plants in loose Honokaa soil Percentage	Roots of plants in more compact Makiki soil Percentage
Topmost 8 inches	63.9	62.6	64.6
Topmost 16 inches	83.0	82.1	83.5
Topmost 22 inches	90.3	90.0	90.5
Soil from 22 inches downward	9.7	10.0	9.5

Showing distribution of roots of five-months-old D 1135 plant cane in Makiki soil at the left, and a soil from Honokaa containing active aluminum compounds at the right. Roots in both series of soils are free from rots, but the photograph shows the small amount of roots found in the aluminum soil as contrasted with the Makiki soil. Distribution of roots in both types of soil shows more than 60 per cent of the roots in the topmost 8 inches of soil and 90 per cent of the roots in the topmost 22 inches of soil.

Such root studies as these are extremely slow, and expensive to carry into a large number of replications. The figures from the foregoing six plants, however, coincide to such a remarkable degree that apparently large numbers of plants are not necessary.

The relationship of such root distribution to problems of field preparation, cultivation, irrigation and fertilization seems equally as important as in the problems of root injury.

Studies planned by H. Atherton Lee.

Cane planted by D. M. Weller.

Root determinations by Clyde C. Barnum and D. M. Weller.

The Common Grasses in Hawaii in Relation to Mosaic or Yellow Stripe Disease

By H. Atherton Lee

A number of grasses which occur as weeds in cane fields show mosaic disease symptoms similar to those of mosaic disease in sugar cane. The following illustrations are presented here as a possible aid in the recognition of these grasses which serve as sources for infection to the cane.

Fig. 1 shows the grass most commonly affected with mosaic disease on unirrigated plantations. It is known locally as *kukai pua* grass, and since it is so widely known by this name we mention it here to aid quickly in recognition. It is usually a recumbent or semi-recumbent grass with hairy leaves and stems. The seeds are borne on a head which is distinctive in that the branches of the head do not expand outward but elongate in a closely held group; this is shown in the illustration. It is a species of the genus *Syntherisma, Syntherisma pruriens.* Other species of this genus are also commonly affected. This grass, *Syntherisma pruriens,* is not so common on irrigated plantations, although occasionally it is found. We have shown experimentally, here in Hawaii, that the mosaic disease of this grass is transmitted to cane.

Another commonly affected grass of the same genus is crab grass, *Syntherisma sanguinalis.* It is found commonly on unirrigated plantations on the windward slopes, although it does not occur as generally as the grass just mentioned, *Syntherisma pruriens.* Crab grass is also recumbent and hairy, but is not as large as *Syntherisma pruriens,* and the branches of the head on which the seeds are borne extend out laterally, often at an angle of 90 degrees from the stem. This enables easy distinction from *Syntherisma pruriens,* as shown in Fig. 2. Brandes, of the U. S. Department of Agriculture in Washington, showed experimentally that the mosaic disease of sugar cane was transmitted to this crab grass.

A third grass of this same genus is what we call creeping crab grass, *Syntherisma debilis.* It is a much smaller grass than either of the two just men-

Fig. 1. *Syntherisma pruriens*, Pig grass.

tioned, but with the head upon which seeds are borne, in general appearance similar to these other two. We have no illustration for this grass. A mosaic disease which we have never tested out to show its identity with sugar cane mosaic occurs upon this creeping crab grass. By analogy with the mosaic diseases of the other two species it seems very probable that it is the same disease.

Fig. 2. *Syntherisma sanguinalis*, Crab grass.

The corn aphis which transmits mosaic disease of sugar cane multiplies itself on all three of these grasses. We feel, in fact, that all the grasses of the genus *Syntherisma* should be regarded with suspicion as sources for infection of sugar cane. All three of these grasses commonly occur along roadsides and often along the edges of fields where the cane does not shade in. In fields, however, they are all commonly killed out when the cane shades in. Hitchcock considers all three of these species as introduced grasses.

On irrigated plantations the grass most commonly affected with mosaic disease is fox tail, *Chaetochloa verticillata*. Kunkel, in the *Planters' Record* for July, 1922, called attention to the mosaic disease of this grass as a possible source of infection for mosaic disease in cane. Since then we have experimentally transmitted the disease from fox tail to cane, proving the relationship of the disease in fox tail, as a source for the infection of cane in the field. Fox tail grass is shown in Fig. 3. Fox tail is a soft, succulent grass, usually erect, with a somewhat flattened stem, and the head upon which the seeds are borne is erect, cylindric, bristly, about 2½ inches long. This is the grass from which the bristles come which are frequently found sticking to a person's clothes. The corn aphis has been found breeding on this grass abundantly. Fox tail is an introduced grass in these Islands.

Fig. 3. *Chaetochloa verticillata*, Bristly Foxtail.

Goose grass, *Eleusine indica*, is a common weed on both irrigated and unirrigated plantations. It is not as frequently affected with mosaic disease as the species previously described, but occasionally shows symptoms of mosaic. Chardon, in Porto Rico, also mentions this grass as a source of infection to cane in that country. It is an erect grass, as contrasted with most of the *Syntherisma* species and grows in clumps rather than making a matted growth. The most easily recognized feature of this grass is the head, which consists of 3, 4, or 5 distended branches bearing closely packed seeds. The illustration in Fig. 4 enables one to recognize this grass much more readily than is possible from a written description. Hitchcock states that it is an introduced grass, originally found in India.

There are two grasses which occur commonly in wet places, such as rice paddies or in stilled water in irrigation systems. One of these is called paddy grass, and the other is known in the Eastern States of the mainland as the barnyard grass. Brandes has found that barnyard grass, *Echinochloa crusgalli*, can be infected with the mosaic disease of sugar cane. We have found the closely

Fig. 4. *Eleusine indica*, Goose grass.

related paddy grass, *Echinochloa colonum*, occasionally affected with mosaic disease in the fields, and by analogy with the other cases feel that it is probably identical with sugar cane mosaic. Both of the *Echinochloa* species occur in more or less erect clumps and are most easily distinguished by their branching heads as shown in Fig. 5.

Fig. 5. *Echinochloa colonum*, Paddy grass.

The corn aphis, *Aphis maidis*, feeds and multiplies itself upon all of these grasses which have been mentioned.

There are other grasses which contract mosaic disease which do not seem to be important as sources for infection of sugar cane. One of the forest grasses, *Isachne distichophylla*, has been observed on Kauai affected with mosaic disease, but it occurs so seldom in the vicinity of cane fields that as a source of infection for cane it does not seem important.

The True Seeds of Grasses Do Not Transmit Mosaic Disease

Although seed cuttings from plants affected with mosaic disease transmit it in 99 out of 100 cases in which they are planted, the true seeds of grasses have never been found to transmit the disease. Brandes, in Washington, tested out the true seed of mosaic-affected corn, sorghum, crab grass, and two other grasses, but in no case did the resulting seedlings show mosaic disease. Here in Hawaii, we have tested out the true seed from mosaic-affected Tunis grass, and Sudan grass, and in no case was mosaic disease inherited by the seedlings.

This has an important significance in plantation prevention of mosaic disease, for it means that if the vegetative parts of the grass are hoed out and killed, the seed which may be on such plants, even if it should germinate, would not transmit the disease. Elimination of sources of infection in grasses as weeds is thus made much easier.

Mosaic Disease in Weeds Which Are Not Grasses

The common weed honohono, *Commelina* species, is frequently seen with mosaic disease. Lupines and the sensitive plant found in fallowed fields also frequently show mosaic disease symptoms. The identity of the mosaic disease of

these non-grasses with the mosaic disease of sugar cane has never been established. However, should this mosaic of these non-grasses be identical, such weeds as honohono and the lupines would not seem to be important as sources for the disease in cane, since the corn aphis does not commonly feed and multiply upon these non-grasses.

The accumulating field and experimental evidence continues to point to the corn aphis as the principal insect, if not the only one, in transmitting mosaic disease in grasses in these Islands.

Grasses in Which Mosaic Disease Does Not Occur

Some of the most common grasses of these Islands, notably, Panicum grass, *Panicum barbinode;* Hilo grass, *Paspalum conjugatum;* red top, *Tricholaena rosea;* Bermuda grass (manienie), *Capriola dactylon;* and Buffalo grass, *Stenotaphum secondatum,* have never been observed affected with mosaic disease to date. The freedom of these common grasses from the disease considerably lessens the problem of the control of sources of infection for sugar cane.

Cultivated Grasses Which Serve as Sources of Infection

It is now generally known in these Islands that corn is a very dangerous source of infection for mosaic disease in sugar cane. The danger does not exist alone in the corn being commonly infected with mosaic but because the corn aphis multiplies itself so prolifically in corn. Mr. Muir has pointed out that the aphis can be wind borne for several miles, at least. A cornfield to the windward of susceptible cane will therefore allow countless disease-bearing aphis to float down on the cane.

A large proportion of the few serious outbreaks of mosaic or yellow stripe disease which have occurred in these Islands can be traced to the planting of corn along ditches or adjacent to cane fields. There seems to be little or no advantage to be gained from such corn plantings, since Professor Krauss, of the University of Hawaii, states that corn growing in these Islands is not a profitable crop.

The same is true of sorghum, since it is just as commonly affected by mosaic as corn, and the corn aphis multiplies itself fully as abundantly on sorghum as on corn. Many of the millets also contract mosaic disease, but fortunately they do not seem to be grown commonly in these Islands.

Tunis grass and Sudan grass, sometimes grown for forage, are also dangerous sources for infection of cane with mosaic disease; both grasses contract mosaic disease readily and on each the corn aphis multiplies abundantly.

There are two common grasses which we regard with suspicion although we have never observed mosaic disease in them. Johnson grass, *Holcus halepensis,* and Job's tears, *Coix lachryma-jobi,* are both plants upon which the corn aphis multiplies abundantly, but although we have seen leaves which showed suspicious symptoms of mosaic, none of the cases could be definitely called mosaic.

There are many forage grasses which do not commonly become affected with mosaic. Two such grasses upon which we have never observed mosaic disease in these Islands are elephant grass and Panicum grass.

Aids to Keeping Down Grasses in Cane Fields

Shading in by the cane, of course, eliminates many grasses as weeds. Anything to hasten the shading in of the cane thus contributes to lessening mosaic disease sources in weeds. Good sized seed cuttings with good eyes, not too hard, will shade in more quickly than small sized seed or seed with hard eyes. Early fertilization and irrigation contributes to keeping down mosaic.

Conversely, such practices as cutting back not only bring the cane back to a level where its leaves mingle with the weeds, but the period during which such grasses as weeds serve as sources for infection is doubled. Every time cane is ratooned the opportunities for spread of infection are greatly increased; much the same thing occurs when cane is cut back.

The practice of the laborers in planting corn along ditches is the worst thing possible and seems to be obsolete now in this country. The practice of planting sweet potatoes along ditch edges, firebreaks and roadside edges seems to be decidedly beneficial. Sweet potatoes do not show mosaic disease symptoms in these Islands and are not sources upon which the corn aphis can multiply abundantly; moreover they shade in disease-carrying weeds effectively.

Olaa Plantation has, of course, used weed poisons in their fields for years, and more recently the Onomea Sugar Company has mounted a small motor-driven paint-spray machine on a light truck and weeds along the edges of the fields are sprayed with weed poisons. Such practices aid in keeping down sources of infection in the grasses as weeds.

In our earlier studies of mosaic disease, planters told us that good agriculture would prevent mosaic disease; at the time we could not see the relationship between the two. It has gradually become apparent, however, that the prevention of grasses as weeds is extremely important, and good agriculture, as shown by prompt fertilization, irrigation, shading in of the cane, and other methods of weed control, contributes in a large way to keeping mosaic disease minimized in these Islands.

Summary

1. Crab grass, fox tail and several other grasses which occur as weeds in cane fields contract a mosaic disease which is identical with the mosaic disease of sugar cane. These grasses are also hosts upon which the insect which transmits mosaic disease, the corn aphis, multiplies itself abundantly. Such grasses are, therefore, important sources for infection of the cane with mosaic disease.

2. The true seeds of such grasses do not transmit the disease to resulting seedlings. Thus if the vegetative parts of these grasses are hoed out and dried up, such sources of mosaic infection in the weeds are eliminated, even if the seeds germinate and develop.

3. Not all grasses as weeds act as sources of infection for mosaic disease. In these Islands such common grasses as Hilo grass, Panicum grass, red top, Bermuda grass (manienie), and Buffalo grass have never been observed affected with mosaic disease.

4. Although several weeds which are not grasses show evidences of a mosaic disease, such weeds would not seem to be important sources for the in-

fection of cane, since the corn aphis which transmits mosaic does not commonly multiply on these non-grasses.

5. There are several cultivated crops which are grasses, and which contract the same mosaic disease as sugar cane, and upon which the corn aphis multiplies prolifically. Corn is, of course, well known as such a source for infection and sorghum and such forage grasses as Tunis grass and Sudan grass are equally as dangerous near cane fields.

6. Agricultural practices which aid the quick shading in of cane, and other methods of keeping down grasses as weeds, contribute considerably to lessening mosaic disease outbreaks.

We are indebted to the Bishop Museum for the illustrations of grasses, which were taken from *The Grasses of Hawaii,* by A. S. Hitchcock, and reproduced in this discussion. Figs. 2 and 4 originally came from Bulletin 772 of the U. S. Department of Agriculture. Figs. 3 and 5 originally came from Volume 22 of *Contributions of the National Herbarium.*

Lime for Upper, Acid Fields

Koloa Experiment 20—1926 Crop

By J. A. Verret

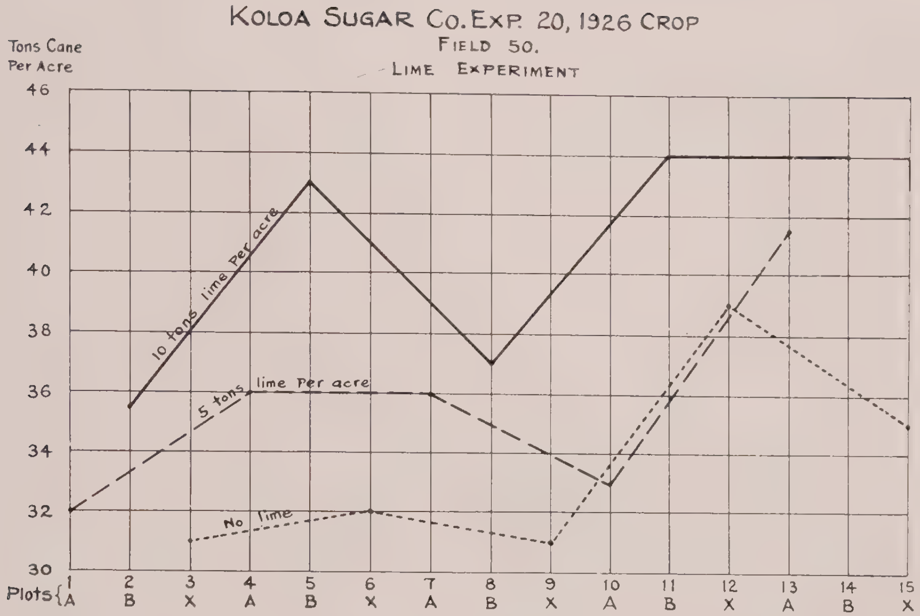
The experiment was located in Field 50, unirrigated, at an elevation of 500 feet. The cane was Yellow Tip planted in April, 1924, and harvested in March, 1926.

The experiment consisted of 15 plots. Five received no lime, 5 plots were limed at the rate of 5 tons of quicklime per acre and 5 plots at the rate of 10 tons per acre. All other fertilization was uniform to all plots and was done by the plantation. The soil in this field is decidedly acid, having a pH of 5.2.

The results are very definite and decidedly in favor of lime, as shown in the chart given herewith. In all cases the no-lime plots produced less cane than the adjoining limed plots. This is well shown in the chart. The results show that large amounts of lime are needed. The plots getting 10 tons of lime per acre without exception gave larger yields than the adjoining plots. The average gain was over 7 tons of cane per acre over the no-lime plots.

The limed plots had poorer juices than the no-lime plots, so the gains in cane weights are not reflected so strongly in the sugar yields. We feel that had this test been harvested later in the season, giving the cane more time to mature, better sugar yields would have been obtained.

Rat and borer damage was somewhat extensive in this area. It is to be expected that there was more damage in the ranker, more succulent cane in the limed plots, although this was not determined by actual count.



We hope to continue this test for a number of crops to determine the effect of lime on succeeding crops. Even larger gains may be looked for as the lime slowly reacts with the soil.

DETAILS OF EXPERIMENT

Koloa Sugar Company—Experiment 20, Field 50.
Lime Experiment—Comparing varying amounts of lime with no lime.
Cane—Yellow Tip; Plant; Unirrigated.
Planted April, 1924. Area, 1.467 acres.
Harvested March, 1926.

Fertilization

Plots	No. of Plots	Lime—Lbs. per Acre
A	5	5 tons—10,000 lbs.
B	5	10 tons—20,000 lbs.
X	5	0 0

All other fertilization uniform to all plots.

PLOT YIELDS

Plots	T. C.	Acres	T. C. P. A.	Brix	Pol.	Pur.	Q. R.	T. S. P. A.
1A	3.205	.10	32.05	15.4	12.05	78.2	12.2	2.63
4A	3.677	.10	36.05	....	.....	....	....	2.95
7A	3.597	.10	35.97	....	.....	....	....	2.95
10A	3.330	.10	33.30	....	.....	....	....	2.73
13A	4.150	.10	41.50	....	.....	....	....	3.40
Total	17.959	.50	35.91	15.4	12.05	78.2	12.2	2.94
2B	3.555	.10	35.55	15.2	11.81	77.7	12.56	2.83
5B	4.295	.10	42.95	....	.....	....	.....	3.42
8B	3.695	.10	36.95	....	.....	....	.....	2.94
11B	4.435	.10	44.35	....	.....	....	.....	3.53
14B	4.417	.10	44.17	....	.....	....	.....	3.51
Total	20.398	.50	40.79	15.2	11.81	77.7	12.56	3.24

3X	3.122	.10	31.22	15.6	12.67	81.2	11.2	2.79
6X	3.230	.10	32.30	....	.....	....	....	2.89
9X	3.067	.10	30.67	....	.....	....	....	2.74
12X	3.887	.10	38.87	....	.....	....	....	3.47
15X	3.502	.075	35.02	....	.....	....	....	3.13
Total.......	16.808	.475	33.61	15.6	12.67	81.2	11.2	3.00

SUMMARY

		Tons per Acre		
Treatment	No. of Plots	Cane	Q. R.	Sugar
5 tons lime.......................	5	35.91	12.2	2.94
10 tons lime......................	5	40.79	12.56	3.24
No lime	5	33.61	11.2	3.00

Honokaa Sugar Company and Pacific Sugar Mill Fertilizer Experiment

By E. E. Naquin

Since 1916, due to economic conditions, potash and phosphoric acid were eliminated as fertilizing materials, and for the past ten years nitrate of soda has been applied almost exclusively on these two plantations. The manager was fully aware, however, that after potash and phosphoric acid had been exhausted these two elements would again become necessary to crop production.

Extensive field and observation tests were constantly carried on, so that we might anticipate this necessity.

Up to 1923 there was no indication of the lack of any other plant food than the nitrate of soda, which we were applying. Since then, however, several field tests have shown conclusively that the lack of potash and phosphoric acid is now being felt.

This was especially noticeable in Field 28, at Honokaa, where part of the cane was harvested without burning off and part after burning. The young cane which came up in the burned area showed such a marked improvement over the young cane in the non-burned area that we suspected the mineral constituent of the ashes to be the prime factor. Tests were then started in this field to show to what extent potash and phosphoric acid were necessary. (See Table I.)

The experiment just harvested showed a gain of 1.17 tons of sugar per acre directly traceable to potash; phosphoric acid alone gave .63 ton of sugar more, while potash and phosphate gave no greater yield than potash alone.

Mill ashes, at the rate of 4,000 pounds per acre, gave an increase of .61 ton of sugar per acre.

In these experiments 186 pounds of nitrogen, in the form of nitrate of soda, was also applied. The soil in this particular portion of the field is considered the best on the plantation and has always given us exceptionally high yields,

averaging close to 45 tons of cane per acre. This fact is probably responsible for the good showing made with potash and phosphoric acid in this instance. The high yields obtained from previous crops have undoubtedly drawn extensively on the reserve of these two elements and depleted these soils to such an extent that an immediate gain is noted when they are applied.

The plant food requirements of the different varieties vary considerably as shown by laboratory tests (see Table II) of the amount of phosphoric acid in juices of several of our standard varieties at Honokaa. As a rule D 1135 requires very much less phosphoric acid than does Yellow Caledonia and Yellow Tip.

Fig. 1. Note heavy growth in background, where potash has been applied, as compared with the sparse growth in the foreground, which received no potash. The variety is D 1135.

Whether these same varieties react in a similar manner toward potash, silicate and the other mineral constituents of a normal growing plant is yet to be determined.

From our observations, since 1916 to date, it is quite evident that potash and phosphoric acid are becoming more and more important factors in crop production, and in the case of phosphate, at least the requirements of the different varieties vary considerably (see Table III) and that the symptoms, heretofore known as root rot or Lahaina disease, can be corrected by heavy applications of potash.

Fig. 2. The response to potash is shown by the higher cane in the background, as compared with the cane in the foreground receiving no potash. Phosphate in addition to nitrogen has but little effect, as may be seen by comparing the two plots in the foreground.

Fig. 3. The response to phosphoric acid in this field is clearly denoted in the heavy growth on the left as compared with that on the right. The variety is Uba.

TABLE I

FERTILIZATION EXPERIMENT

H. S. Co. 25, Field 28, D 1135, 2nd Ratoon, 1,000 ft. Elevation, Harvested July, 1925

No. of Plots	Fertilization N	P_2O_5	K_2O	Ashes	Juice Analysis (Crusher) Brix.	Pol.	Pur.	Q.R.	Tons per Acre Cane	Sugar	Gain or Loss Sugar
4	186	0	0	0	16.71	15.26	91.32	8.55	41.69	4.87	
2	186	200	0	0	16.94	15.61	92.15	8.31	45.14	5.50	+ .63
4	186	0	0	0	16.71	15.26	91.32	8.55	41.90	4.90	
2	186	0	200	0	16.94	15.61	92.15	8.31	50.44	6.07	+1.17
6	186	0	0	0	16.71	15.26	91.32	8.55	52.94	6.19	
5	186	200	200	0	16.94	15.61	92.15	8.31	61.17	7.36	+1.17
4	186	0	0	0	16.71	15.26	91.32	8.58	54.97	6.40	
2	186	0	0	4000	16.94	15.61	92.15	8.31	58.28	7.01	+ .61

TABLE II

Average Per cent Phosphoric Acid in First Mill Juice of Different Varieties of Cane

Varieties	No. of Analyses	Per cent P_2O_5
Yellow Caledonia	10	.0456
Yellow Tip	8	.0392
H 109	10	.0268
D 1135	10	.0225
[illegible]	5	[illegible]

TABLE III

Object: The effect of complete fertilizer on different varieties in root rot area.

Location: Honokaa Sugar Company, Field 31A, 900 feet elevation.

Crop: D 1135, Yellow Tip, Striped Tip, Yellow Caledonia, Badila and Honokaa No. 1. Planted May 21, 1923.

Plan: These varieties were planted in a diseased area and plots of each variety treated with complete fertilizer with alternate check plots. The treated plots received 400 lbs. P_2O_5 and 400 lbs. K_2O in one dose and all of the plots received 186 lbs. of Nitrogen in two equal doses.

Summary of results—Harvested July 9, 1925:

Nitrate of Soda Variety	Per cent P_2O_5 in Juices	Q.R.	Tons per Acre Cane	Sugar	Complete Fertilizer Variety	Per cent P_2O_5 in Juices	Q.R.	Tons per Acre Cane	Sugar	Gain or Loss Sugar
D 1135...	.023	9.62	55.83	5.80	D 1135...	.025	12.98	82.03	6.31	+ .51
Y. T.....	.025	10.06	38.78	3.85	Y. T......	.060	11.41	116.97	10.24	+6.39
S. T.....	.055	10.18	47.87	4.70	S. T......	.057	12.94	85.84	6.63	+1.93
Y. C.....	.050	9.09	51.47	5.66	Y. C......	.042	8.72	57.91	6.64	+ .98
Badila ..	.045	8.29	54.38	6.68	Badila ..	.032	9.38	52.37	5.58	—1.10
Honokaa 1	.040	9.75	72.72	7.45	Honokaa 1	.028	10.98	71.68	6.53	— .92
D 1135 ..	.023	9.62	44.09	4.58	D 1135...	.025	12.98	64.21	4.94	+ .36

We found from previous observations that Yellow Caledonia gave the earliest [illegible] response to [illegible] and [illegible]. This early response [illegible] the growth and in consequence the ripening of this variety, which may account for the better juices in the treated plots. The response of D 1135,

Yellow Tip and Striped Tip was not so pronounced at the start and may account for the poorer juices in the treated plots of these varieties.

The yield of Badila and Honokaa No. 1 correspond with our previous obser--vations. These two varieties showed but slight response to complete fertilizer. The Badila showed early signs of distress in the non-treated plots, but it soon outgrew this condition. Honokaa No. 1 showed equally as good in the non-treated plots as in the treated plots at all stages of growth.

The percentage of phosphoric acid in the juices has a tendency to be higher in the treated plots.

Field Losses

By A. T. Spalding

The writer visited a number of plantations on the Hilo coast during the harvesting season of 1925 and noticed a good many fields where high stubbles were left on the ground. Few of us realize just how much cane can be left on the ground until you check up by cutting and weighing it. We hear about recovery and losses in the milling department and strenuous efforts are usually made by the mill hands to recover as much sugar as possible. It is easy to lose one per cent in the mill, but it is easier to lose double that in the field if one is not careful. Since getting in so many new Filipinos who have had little or no experience in cutting cane, the head and section overseers have had more or less worry getting clean fields. Where cane is burned the results are usually very good, but along the Hilo coast where burning is not practiced much there is considerable loss in the leaving of high stubbles.

The writer, at the beginning of the 1925 harvesting season, had an opportunity to find out losses incurred by the leaving of high stubbles. The figures submitted are no doubt above the average, but it is desired to bring out that the point of careless harvesting can soon amount to money. The man doing the cutting was a new Filipino who did not know how to use a knife. It was probably his first attempt at cutting cane and after he was shown the proper method he made a good showing. However, if we should even consider the half of this loss it would amount to a great deal in the course of a crop. The lower part of the stalk, as we all know, is rich in sucrose and juice analysis was not taken. The following figures are submitted:

Length of Row	Gross Lbs.	Tare Lbs.	Net Weight	Cane per Acre
102 feet	38	4	34	2727 lbs. (5½ ft. rows)

Nematode Parasitic Upon Termites

The following translation of a paper by C. Lespés[1], published sixty-nine years ago[2], is of interest to us on account of the damage done by white ants, or *Termites,* to property in our islands.

In the course of my observations on the *Termites,* I have twice seen numerous nests, which appeared to be in a state of great prosperity, entirely destroyed in a few days. These two societies were established with me in large glass-vessels, but the earth of the nests was too moist; in this earth I then saw an immense number of little white worms swarming, and by examining them carefully and dissecting the *Termites* of these societies, I have been enabled to ascertain the history of the parasite. In its characters this Nematoid worm closely approaches *Leptodera* of Dujardin, but it must form a distinct generic group, as several of its characters differ from those of *Leptodera*—its mouth is armed with three tubercles, its neck is short and thick, and lastly it is oviparous, whilst *Leptodera* is viviparous. The characters of the generative armature of the male are identical, but the aliform expansions so remarkable in M. Dujardin's worm are wanting in mine.

(Here follows a description of the nematodes.)

The adult males and females of this species are common in the earth of the two nests. They presented the remarkable property of being capable of being recalled to life after complete desiccation for more than a month. The males are rather less abundant than the females.

In these little creatures we may perfectly distinguish the digestive tube, which commences with a muscular pharynx, followed by an intestine which is straight in the male, and twisted into a spiral in the female. The former presents a slight tubercle a little above the tail; in the corresponding part we see the two spicules of 0.05 mil. in length, and the sheath of 0.02 mil. which is placed below. The generative orifice of the female is placed about the middle of its length; by transmitting light we see a great number of eggs filling the body.

With these animals I found an immense number of free eggs in different stages of development. Those furthest advanced contained an extremely mobile embryo. Some of these escaped, but there was still a gap between the young individuals and the adult or nearly adult forms. To supply this it is sufficient to dissect a *Termite* of the infested nest, when we find in the abdomen, around the intestine, but never in its interior, some Nematoid worms, very short and slender when compared with the adults; they are in different stages of development, but the generative organs are always wanting. I found from one to six of them, but only in individuals of a certain size (workers, soldiers, nymphs). All my observations were made at the beginning of May, and in the second nest I verified them in June. The infested insects soon languish and at last die; if they are then examined, the developed Nematoid worms are seen issuing from their bodies, which are becoming putrefied.

From these facts I think that all naturalists will admit with me, that the parasite of which I have just given the history, acquires its generative organs and propagates in moist earth; that the young penetrate into the bodies of the *Termites*, become developed there, finally destroy their victim, and then escape to complete their growth.

The study of the probably numerous worms which have been united under the name of *Filariae* of Insects, was commenced by the remarkable work of Von Siebold upon *Mermis albicans.* The facts which I have just described, seem to be a copy of those made known by that learned naturalist.

In the digestive table of the *Termites,* I have found a considerable number of parasites.

F. M.

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[1] Ann. Sci. Nat., V., Zool., p. 335.

[2] Ann. Mag. Nat. Hist. Second Series, Vol. XIX, 1857, p. 388.

U. D. 92

One of the Uba hybrids which offers promise on account of having a fair sized stick, fair sugar content, heavy stooling properties and drought resistance. The clumps shown here are plant cane from seed pieces spaced five feet apart.

So-called Fillers in Mixed Fertilizers

By C. G. Owen

In order to help clarify a situation which exists and proves a great annoyance to fertilizer manufacturers and is the cause of misunderstandings on the part of consumers of commercial fertilizers, the following facts are put forth and should be more generally known.

The term filler is assumed to be any material added to a mixed fertilizer, which is not required to satisfy the analysis called for. It will be seen immediately that any composition which calls for a mixture of raw materials to satisfy a required analysis and which weighs less than 2,000 lbs. must have weight added to secure the ton unit generally used in fertilizer calculations.

Most times the supposed amount of filler used is more apparent than real because the raw materials in the composition of a complete commercial fertilizer are of great variation, for instance—

Superphosphate analyzes from 16 per cent P_2O_5 to 20 per cent P_2O_5, according to the grade of phosphate rock available to the manufacturer. Other ingredients range as follows:

Bonemeal, from 18 per cent P_2O_5 to 26 per cent P_2O_5, 2½ per cent nitrogen to 4 per cent nitrogen.

Potash materials, such as sulphate of potash, muriate of potash, double manure salts, kainite, potash nitrate—from 14 per cent K_2O to 58 per cent K_2O.

Nitrate of soda from 14½ per cent nitrogen to 16 per cent nitrogen.

Sulphate of ammonia from 20 per cent nitrogen to 21 per cent nitrogen.

Dried blood and other organics from 9 per cent nitrogen to 14 per cent nitrogen.

On account of these wide variations it will be seen that a considerable choice can be had in making up any required formula. On this account formulas that call for raw materials which by weight total 1,925 lbs. or over should be considered fertilizers without fillers. The difference between 1,925 lbs. and 2,000 lbs. is a necessary allowance to give a choice of grades in the raw materials mentioned in accord with market conditions. Any insistence on a definite composition of raw materials results in a higher cost and is therefore impractical.

The average complete fertilizer is composed of about seven different chemicals or raw materials and if an allowance of only 10 lbs. for each ingredient is figured it will be seen a necessary leeway of 70 lbs. results.

Again, any required formula cannot be figured safely to the second decimal point, as owing to the different specific gravities of the materials involved no mixture would remain accurate upon the slightest agitation of transportation and handling; consequently the manufacturer must figure in excess to the extent of about two-tenths of 1 per cent to avoid the possibilities of claims for shortage. This results in an additional leeway of 40 lbs. per ton, the same being 2 per cent of 2,000 lbs.

For the sake of argument let us assume that no leeways are calculated, and to satisfy a given formula about 1,900 lbs. of materials to the ton are required, the question then is what shall compose the extra 100 lbs. to make up the full ton? The manufacturer has a choice first of choosing a lower grade of any of the materials making up the composition or can use carbonate of lime or sulphate of lime, which are considered of agricultural value.

A paradox in regard to this subject exists, for if one purchases, we will say, nitrate of soda which contains 15.5 per cent nitrogen, it is considered without filler, although as a matter of fact the nitrogen is only what is required and there is really 84½ per cent filler, which obviously cannot be avoided; yet if a customer ordered a fertilizer containing 15½ per cent nitrogen from sulphate of ammonia, which would call for but 1,500 lbs. of this chemical, then 500 lbs. of some other ingredient would have to be used, and it would be considered a fertilizer with a filler. The question is, why should this be and how can further endless discussion on this subject be avoided?

As time goes on and the chemical industry finds methods of producing at comparative costs still higher concentrated goods the more we will hear of the so-called filler. In fact, if the concentration reaches too high a point it will probably be necessary to dilute such chemicals, as their use in the concentrated form in large quantities might prove detrimental to plant culture, or they may have to be diluted in order to get better distribution on the field.

Perhaps this question can never be settled, but in order to secure a closer understanding and cooperation between the manufacturer and his clients we believe a line should be drawn somewhere and we suggest 1,925 lbs. as the basis for discussion.

An Authentic Bud Variation in Potato*

As recently as 1918 so experienced a plant breeder as A. Sutton expressed the view that "there is no ground for believing nature ever has given rise to any new and distinct variety of potato by bud-variation." The point at issue is of first-rate importance, both scientifically and from the practical point of view, and it is therefore very interesting to have R. N. Salaman's confirmation, as the result of extensive breeding experiments, of Mr. McKelvie's original view that he had found an authentic bud sport turning up in the case of the Arran Victory potato. Thus sponsored, this bud sport, or somatic mutation, deserves the most serious consideration. Actually a series of such sports has been under observation, the obvious point attracting attention to them being the suppression of patches of the purple coloration in the skin, leading ultimately to a form with white tubers with occasional patches of color, or, in the extreme form, tubers with a pure white skin. Most of the forms thus arising produce plants with vegetative form and foliage

* From *Nature*, October 17, 1925, No. 2920, Vol. 116.

indistinguishable from Arran Victory; but one remarkable mutant has definitely a different growth form and different shaped leaflets, a point noticed by McKelvie and completely confirmed by Salaman. This same mutant also shows the tuber form altering in a large majority of its produce from the typical round tuber of Arran Victory towards a typical "kidney." Mr. Salaman has carried out crossing experiments with these bud mutations, with the result that the loss of pigment in the tuber appears to be accompanied *pari passu* with a reduction in the number of ovules capable of giving rise to colored tubers. Thus it appears that a change arising in a vegetative shoot and propagated in the first place vegetatively, a change presumably in the genes controlling color formation in the tuber but, in one mutant form at least, associated with other far-reaching changes in the constitution of the plant, has been associated with changes in the genetic constitution of the germ cells. Mr. Salaman describes his breeding experiments in the *Journal of Genetics* (Vol. 15, No. 3, July, 1925), his final conclusion being that "A somatic mutation which is characterized by the loss of a specific character such as pigmentation of the tuber skin, may evince this loss in other directions both in its own body and, through its germ cells, in its offspring."

[J. A. V.]

The Influence of the Cattle on the Climate of Waimea and Kawaihae, Hawaii

From the *Sandwich Islands' Monthly Magazine*, Issue of February, 1856

That clearing the land ameliorates the climate, is an established fact in the science of Meteorology, but in the instance now under consideration, there are circumstances which appear to render the case peculiarly interesting. In the first place, all the phenomena concerned are within comparatively confined limits. One can stand on a point of rock and include at a glance the whole theatre of operations. The time in which the change of climate has been effected is short, and within the memory of men now living in the district, and the change itself is so palpable as to have rendered an old established custom of the natives no longer necessary. In the second place, the locality being on an island within the range of the steady trade winds, it is out of the reach of the numerous complicating and disturbing causes which effect atmospheric phenomena in regions differently circumstanced. And finally the chain of causes and effects produced is more extended than appears to be the case in most other instances.

The Waimea plains may be described as an elevated plateau, some ten miles long, four or five miles wide, and perhaps four thousand feet above the level of the sea. At each end they are bounded by a steep slope towards the sea. On one side of the plain is Mauna Kea, and on the other the Kohala range of hills. The northeast trade wind blows almost directly along this plain, and being drawn, as it were, between two mountain ranges, is generally pretty strong. Kawaihae is situated on the beach at the bottom of the slope on the lee or western side of

the elevated plateau. The trade wind does not usually blow at Kawaihae; it seems, after sweeping the plains, to continue a straight course without descending the slope, leaving that place under the influence of the regular land and sea breezes. On travelling in the day time from the beach up the hill towards Waimea, we generally start with the sea breeze behind us, which continues until we get to about the brow of the rise—we then arrive at a region of calm—of only a few hundred yards in extent, however—for almost immediately we are met by the cold trade wind in our faces. If the journey be made at night, we usually start with a gentle air from the land, which gradually dies away as we ascend, until reaching the brow as before, the same cold breeze salutes us, and bitter cold it often feels, on so suddenly leaving the hot region below. Two marks might be set up only a few hundred yards from each other, which would probably for three hundred days in the year, include the debatable ground between the limits of this cold trade wind, and the warmer land and sea breezes below. There are, however, disturbing causes, one is the southerly wind which at certain seasons prevails over all this part of the ocean, and when prevalent annihilates for the time all the winds just alluded to. The other is the wind which we have more particularly to consider in relation to our present subject.

This is the wind called *Mumuku,* the tremendous gusts which occasionally sweep down the slope towards Kawaihae, whirling clouds of dust out to sea, blowing sometimes all day and night, when, of course, the usual land and sea breezes are destroyed. It is nearly coincident in direction with the trade wind, and also with the land breezes, that is to say the three winds, although independent of each other, *all blow in the same direction.* The trade wind and the southerly wind, are independent of local circumstances—but the land and sea breezes at Kawaihae and these *mumukus* are peculiarly local winds, and are effected by local circumstances. The following extract from Brande's Encyclopedia is a succinct and easily intelligible account of the cause of land and sea breezes:

> During the day the surface of the land becomes more heated than that of the adjacent ocean, and the air over the land, in consequence of its greater rarefaction, is displaced by the denser air rushing from the sea. Hence a current, or *sea breeze,* beginning at the same hour in the morning, and continuing till the sun is near setting, will flow from the water towards the land. At night the water remains warm, while the surface of the land cools rapidly; and hence the current sets from the land towards the water, and forms the *land breeze.*

The two main causes which we find adduced to account for winds and storms in general are, the difference of the temperature of the atmosphere in two regions, and the sudden condensation of vapor, by which the equilibrium of the atmosphere is destroyed—and the wind is the rush of air to restore it. It follows, therefore, that the greater this difference of temperature, or the greater the amount of vapor to be condensed, so much more violent will be the resulting winds and storms.

In the case before us then it is not difficult to perceive a very fertile cause of the *Mumukus,* for we have a cold moist trade wind approaching a current of air at a comparatively high temperature, for the latter although originally a sea breeze and tolerably cool, before it meets the trades, has passed over four or five miles of black lava rock heated perhaps by an afternoon tropical sun. Any cause disturbing the equilibrium of these currents would be likely to produce very

violent motion. Let us suppose one case—a strong trade wind sweeps over the plains heavily loaded with moisture, so much so that a portion falls in rain over the heated lava rocks on the slope towards Kawaihae—this suddenly cools them—the circumstances which were producing the sea breeze are reversed, the causes which produce the land breeze are in operation—the direction of the current of air is suddenly altered, whilst a steady gale is at hand, to back up the local rush of the cooled atmosphere to the now warmer regions at sea.

Fortunately these hurricanes are now not nearly so violent or frequent as they used to be some twenty-five or thirty years ago. The old residents all affirm this, and they state that formerly the *Mumukus* were so common and violent, that the natives made a regular practice of lashing their canoes which were hauled upon the shore to a rock, stake or tree, to prevent them being blown off the land into the sea. This practice is now given up, being no longer necessary.

But what have the cattle on Waimea plains to do with these hurricanes?

It is in the memory of many foreigners now living there, when the whole of these plains were covered with a thick wood, to the very edge of the slope. Where now hardly a tree is to be seen for miles, we were informed by an old resident, that twenty-five years ago he lost himself with his team in the woods. He also stated that at that time there was far more rain at Waimea than there is now, which indeed might be readily inferred, as clearing the land of trees invariably lessens the quantity of rain. This clearing of the land has been almost entirely effected by the cattle. The few head brought by Vancouver in 1793 increased so rapidly, that early in the present century thousands of them were killed for their hides. At this moment they swarm in the thick jungle that covers the windward or eastern slope towards Hamakua. They are now gradually destroying this, and thousands of old dead trees, both standing upright and lying prostrate, form the present boundary of these woods, and exhibit the mode in which the destruction is effected; for whilst the old trees die of age, no young ones are seen taking their places, as during the last thirty or forty years, the cattle have eaten or trodden them down.

At the present time the vapors and rain which are brought across the plain by the trade winds are generally dissipated between Waimea village and Lihue, which latter place is something under a mile nearer the brow of the hill, and it is quite usual to notice that at Lihue the weather is fine and the sun shining, whilst at Waimea it is wet, raw and misty. This spot where the vapors now commonly terminate, is three or four miles from the debatable ground between the two winds before alluded to.

But when some twenty-five or thirty years ago, woods extended over the whole plain and to the very edge of it, close on to this debateable ground—and when rain was in consequence more frequent over this district, the vapors and cold moist atmosphere, instead of being dissipated near Waimea village, would necessarily have more frequently extended to the debatable ground; so that the peculiar conditions which as we have seen are the main causes of winds, were then greatly intensified and probably at the highest pitch, and instead of a moderate *Mumuku* now and then as at present, these tremendous gusts must have been an almost every day occurrence. The few miles of open warmed ground and sun-

shine now tempers the trade wind before meeting the sea breeze, but when covered with foliage it would have had a contrary effect, by attracting the vapors.

To put the case in a few words—there is usually a much smaller difference now, in the temperature and in the moisture of the conflicting currents of air which are concerned in the formation of these wind storms, than there was before the cattle destroyed the woods; and they are now less frequent and violent accordingly.

When the natives of different districts of these islands tell us that their climate has altered since the white men came amongst them, we are apt to treat their statements as fanciful, and to imagine that there can be no more connection between the two, than there is in the celebrated instance of the erection of Tenderden steeple and the formation of Goodwin sands. The old natives assert that there is *more* rain in Honolulu *now*, than there was before the white men came. This is the opposite effect to the one just treated of and is singularly corroborative of the correctness of the principle adduced; as here the old residents tell us of the time when there was hardly a tree in the lower parts of Nuuanu valley—the white people came and planted them—and now—Honolulu and a large portion of the valley presents to the view, a pretty liberal sprinkling of foliage.

The simple observation of facts by the ignorant and the savage, is often more correct than that of cultivated people, and it would be well to carefully examine all their statements, and ascertain if there is not a reason for them, however absurd they may appear. For, as in the present instance, what proposition seems more unlikely, than that the landing of a few head of cattle at Kawaihae, by Vancouver in 1793, should diminish the violence and frequency of the hurricanes at that place in 1856, and yet a little examination shows it to be in a high degree probable not only that there is a connection, but that it is close and easily traceable. Indeed, we seem to have at Waimea and Kawaihae, a remarkably compact example, a cabinet specimen as it were, of the mutual action and reaction on each other, of earth, air, sea, men, animals and plants.

[L. W. B.]

Explosions in Air Compressors and Receivers*

Explosions in air compressors and receivers occur with sufficient frequency to demand careful attention. The majority of such explosions are undoubtedly due, either directly or indirectly, to the lubricating oil used in the air cylinders. Poor working conditions of the compressor, such as leaking valves, hot and dirty inlet air, insufficient cooling water, carbon deposit in cylinder or connections, and high speeds of poorly designed compressors, all assist in producing dangerously high temperatures of the compressed air. These high temperatures are sufficient to ignite the volatile constituents of the lubricating oil, and produce violent explosions; therefore:

* Taken from *California Safety News*, Vol. 9, No. 4, December, 1925.

(a) Keep the temperature of the compressed air during compression as low as possible.

(b) Keep the piston and valves tight, and in good working condition.

(c) Take the inlet air from as cool and clean a location as practicable.

(d) Use plenty of cold water, from a source which is not liable to fail, and have it visible at discharge from cylinders or coolers.

(e) Do not use kerosene or other volatile substances in the cylinder, tanks or any connections.

(f) Use mechanical or sight feed oilers for the compressor cylinder.

(g) Use the least amount practicable of the best air cylinder oil. Air cylinders require much less oil than steam cylinders.

(h) Never use steam cylinder oil in an air cylinder.

(i) Keep the cylinder, tanks and connections as free from carbon, accumulated oil and deposits as practicable.

(j) A good cylinder oil is one which lubricates well, leaves little or no deposit, is the least volatile at high temperature, and has a high flash point. Observance of the foregoing suggestions will prevent many accidents.

The less a man's time is worth the less willing he usually is to take the necessary precautions for safety.

[W. E. S.]

Pahala Blight and a Comparison with Other Forms of Sugar Cane Chlorosis

By W. T. McGeorge

For some twenty years or more cane grown in many fields of the Hawaiian Agricultural Company in the Kau district on the island of Hawaii has been seriously attacked by a chlorotic disease. Owing to the locality, Pahala, it has from the very beginning been termed Pahala blight, but is also known as the leaf-splitting disease. This latter term was probably derived from the fact that the disease first makes its appearance in the form of yellow stripes along the smaller vascular bundles of the leaves and along which the leaves split during strong winds. The term blight was probably derived from the fact that the fungus or fungi associated with the wilted condition of the plant causes a wilting in the most seriously affected plants. Cobb identified *Mycosphaerella striatiformans* as being active upon affected leaves.

Description of Disease

The following description is given by Cobb in Bulletin 5, Pathological Series, of this Station:

The early stages of the onset are to be observed in cane that is only a few weeks old, but the symptoms are more easily seen in cane that is several months old. It may be observed in cane upwards of a year old, but to plants of that age it does not do so much harm as to younger ones. The earliest symptom is a slight alteration in the coloring of the leaves, this alteration being observed first on the outer leaves, and toward their tips rather than lower down. The alteration in color takes the form of stripes, due to the loss of green color in the tissue carrying the small vascular bundles. On a line half way between the larger fibres or the vascular bundles of the leaves the green color fades and is succeeded by a whitish yellow. At first these pale streaks are narrower than the green streaks that separate them, but as the disease progresses the whitish streaks become wider and the green ones narrower, until at last the greater portion of the leaf is light colored. . . .

The striped appearance begins near the tips of the leaves and occurs on the outer leaves first. As time goes on the inner leaves become affected and the stripes progress downward.

During the striping stage the leaves remain succulent and retain their full width. Leaves in the final stages of the striping process are very conspicuous objects.

When the striping has so far proceeded as to destroy most of the green color of the leaves the lighter portions of the leaves begin to shrivel and assume a dry, whitish appearance such as is characteristic of light-colored dead grass leaves. On examining one of the dry stripes attentively it will be seen to be more or less filled with minute black specks barely visible to the unaided eye. These are small subspherical growths just below the surface of the leaf and the microscope shows that each is a hollow sphere filled with spores.

The following description by Lyon is also of interest:

Pahala blight is in effect a bleaching and destruction of the chlorophyll. As a rule the chlorophyllous tissues around the minor vascular bundles only are affected, the green tissues around the major bundles becoming involved only at a late stage in the disease. As a result a newly affected leaf displays a very definite striped appearance, green stripes alternating with yellowish green or white stripes.

In the affected tissues the chloroplasts first lose their definite outline, then run together in a pale yellowish green mass and finally lose all semblance of green color.

The first indication of an attack of Pahala blight noticeable in a cane leaf is a paling or bleaching of the green tissue at the proximal ends of the minor vascular bundles. The bleaching proceeds upward and outward through the blades of the leaf along these bundles, producing light stripes of uniform width which may eventually extend to the very margin of the leaf. The progress of the disease may be slow or very rapid. In some cases the paling of the tissue in the stripe is very gradual and may not proceed beyond a light greenish yellow; in other cases the paling is very rapid, the tissues being quickly bleached to a sickly yellowish white.

A cane shoot may show a mild case of Pahala blight, continue in the same condition for months and eventually recover. Then, again, the disease may reach an acute stage only a short time after the first symptoms have become apparent, but the shoot usually lingers on for months before it finally succumbs. If the chloroplasts are seriously injured the tissues never recover, but die and are soon invaded by various saprophytic fungi. When canes become seriously affected by the blight they stop growing and remain practically dormant until the blight factor ceases to operate, then they do not recover by rehabilitating the old tissue but produce new and healthy tissue. Consequently they show a very abrupt transition from diseased to healthy tissue. One leaf may be very badly marked by the blight and the very next younger leaf show no sign of the blight at all. Then, again,

the upper portion of the leaf may be distinctly blighted while the basal portion is quite free from blight. In such a case the basal portion has been produced after the blight factor ceased to operate.

The appearance of blighted fields is well illustrated in Fig. 1.

Cobb concluded that the fungus *Mycosphaerella striatiformans* was directly responsible for the disease. Later, Lyon showed that this fungus was saprophytic rather than parasitic and that it only entered the tissues of the leaves after these tissues had been injured by the blight. On this basis and the fact that there were definitely defined areas at Pahala which are always free of blight, Lyon suggested that the blight was induced by a "factor or factors resident in the soil."

Following this a number of field experiments were conducted to determine the relative resistance of varieties and to search for a method for its control.

Resistant Varieties: Observation Test A (1921 crop, Williams) compared Rose Bamboo, Striped Mexican, Caledonia Ribbon, H 72, H 227, H 291, Yellow Bamboo and D 1135. All these varieties became blighted, but D 1135 made a notable recovery and H 72 a partial recovery. D 1135 still continues to be the most resistant variety.

Field Experiments: Observation Test B (1921 crop, Lyon and Williams) compared mud press, stable manure, magnesium sulphate and iron (ferrous) sulphate. Of these treatments stable manure in very heavy applications gave excellent response. There was a slight temporary betterment in leaf color in the iron sulphate plots.

Similar treatments were obtained in Observation Test C. In this case an excellent improvement was obtained by pouring the iron sulphate solution upon the soil around the roots. This greening of the leaves was only temporary, however, and soon disappeared.

In Observation Test D (1921 crop, Lyon, Williams and Alexander) an exhaustive set of field experiments was installed to determine if volcanic gases arising from the subsoil were associated with the disease. For this experiment one-foot excavations were made in a blighted field and a layer of charcoal placed at the one-foot depth. This experiment also included heavy manure applications and a transfer of soil from the Mudflow field to an excavated plot. The Mudflow field has never in the history of the plantation shown any blight. Only the heavy manure application and the transported soil showed normal growth. Cane on the charcoal plot was a total failure.

Observation Tests E and F (1921 crop, Lyon and Doty) were then installed in order to test the effect of spraying a 4 per cent solution of iron sulphate upon the chlorotic leaves. The result of this experiment was that the leaves were badly burned by the spray and there was no sign of a recovery.

Heavy fertilizer applications were tried in Experiment 3A (1922 crop). These included ammonium sulphate, 1,250 pounds per acre; acid phosphate, 500, 1,000 and 1,500 pounds per acre; sulphate of potash, 800, 1,600 and 2,500 pounds per acre, and muriate of potash, 500 and 1,000 pounds per acre. Considerable response to sulphate of ammonia was obtained and some response to sulphate of potash.

A number of green manuring experiments, using eight different legumes, were tried, but with questionable results.

The above is a review of the work which had been done on this problem previous to January, 1924, at which time a request was made for further investigation. The most significant points, that is, those which seem to stand out in these experiments are: (1) the temporary response to iron sulphate when applied in solution to the soil about the roots, (2) the burning of the leaves when this salt is used as a spray, and (3) slight response to sulphates of ammonia and potash, both of which, especially the former, are residually acid fertilizers.

Plan of Investigation

In planning a chemical investigation of this problem it was necessary to recognize a number of different phases which were apparently of more or less equal importance. Among these may be mentioned the poor root development and scanty root system of blighted plants. On digging up such plants the stalk was usually still feeding through the seed piece (plants 10-12 months old), which was still solid and showing little or no signs of decay. The stalk itself had few roots capable of supplying plant food. In direct contrast neighboring plants not attacked by the blight had excellent root systems and the stalks were no longer dependent upon the seed piece for their nutrition. The seed piece on such plants was almost completely decayed and the plant with its own root system was "shifting" for itself. This well developed root system extended 2-3 feet into the subsoil.

The appearance of the leaves suggested chlorosis probably resulting from some form of physiological or nutritional disturbance. On the other hand, in the badly affected plants, that is, the blighted ones, the leaves were severely etiolated, curled, were damping off and gave every evidence of a severe fungus attack which in many cases finally developed into top rot and the death of the plant. Plants showing only the typical chlorosis rarely die and some are even little retarded in growth. In fact, chlorotic and non-chlorotic shoots are often to be noted in the same stool. On this basis it appeared that the chlorosis might be only one of several factors involved as causal agents in this blight. Lyon has reported the same type of chlorosis, namely, the leaf striping, at Waialua Agricultural Company. Cobb reported also seeing it on other plantations. Carpenter reported it at Wailuku Sugar Company. The writer has observed it at Waialua, Ewa, Oahu, Hawaiian Commercial and Sugar Company, Honolulu and Honokaa plantations and also at the Makiki Plots of the Experiment Station. On the other hand, to my knowledge Hawaiian Agricultural Company is the only plantation on which this chlorosis is followed by a blighting of the plant.

Our work was therefore divided into soil studies and a biochemical study of the plant. An additional study was made of soils and plants from a number of areas on other plantations where the chlorosis is not followed by a blight.

Soils

The Hawaiian Agricultural Company is located on the southeast slopes of Mauna Loa and cane is grown up to an altitude of 3,000 feet. The soils are principally silts or silty clay loams of excellent physical texture. The location

of the blighted fields is more or less clearly defined, lying within the range of altitude 1,500-2,000 feet. An exception is the Mudflow field. The soil in this field was formed 50-60 years ago by a mudflow from Mauna Loa. It is an entirely different type from most of the other plantation fields and cane grown on this soil has never been affected by the blight. This would seem to eliminate temperature, rainfall or other environment factors, as well as fungi and bacteria, as being primary causes. It is interesting to note that in going over the fields of Hutchinson Sugar Plantation Company, which are also located in the Kau district, in general their soils are quite similar to the Mudflow type. It should also be mentioned that in several areas scattered over this plantation a few plants may sometimes be found with the typical chlorosis, but the blight has not been observed.

For comparative soil studies samples of soil and subsoil were taken from representative fields, both normal and blighted. A description of these is given, followed by a partial analysis in Table 1:

Soil 1—A brown silt loam from Lower Goodale field; cane very badly blighted.

Soil 2—Subsoil to 1.

Soil 3—Brown silt loam from Lower Stone field; cane badly blighted.

Soil 4—Subsoil to 3.

Soil 5—Yellowish gravelly loam from Mudflow field; no blight in this field. This soil is uniform to considerable depth so that no subsoil sample was taken.

Soil 6—Brown silt loam from Lower Wood Valley field; only traces of blight in this field.

Soil 7—Subsoil to 6.

Soil 8—Brown silt loam from Middle Naahala field; a blight field.

Soil 9—Subsoil to 8.

Soil 10—Black silt loam from lower Clover field; no blight in this field.

Soil 11—Subsoil to 10. In this case the subsoil, unlike the blight fields, does not verge off to the yellow type.

Soils 12 and 13—Black silt loam samples from Meyer field. These are both surface samples, 12 from blight and 13 from around normal cane.

Soil 14—Black silt loam from Mission field; badly blighted field.

Soil 15—Subsoil to 14.

Soil 16—Black silt loam from Middle Moaula field; no blight.

Soil 17—Subsoil to 16.

TABLE 1

Analyses of Soils, Pahala Blight

	Air Dry Soil		Soluble in 1 Per cent Citric Acid				Total by Fusion				
Soil No.	Moisture	Volatile and Organic	Silica SiO_2	Lime CaO	Potash K_2O	Phos. Acid P_2O_5	Potash K_2O	Phos. Acid P_2O_5	Acidity pH	Nitrogen N	Remarks
1	7.10	6.93	.58	.62	.043	.0587	.39	.31	7.0	.39	Blight
2*	8.05	8.67	.54	.49	....	.0044	.22	.52	7.0	.45	"
3	17.47	7.53	.50	.37	.024	.0560	.39	.22	6.9	.40	"
4*	19.43	9.91	.44	.39	.029	.0027	.36	.41	6.8	.42	"
8	8.79	11.41	.48	.48	.093	.0072	.50	.47	7.3	.44	"
9*	14.06	13.39	.42	.45	.114	.0042	.31	.48	7.3	.49	"
12	11.53	13.73	.42	.37	.055	.0049	.35	.60	6.8	.50	"
14	10.03	14.97	.48	.54	.035	.0087	.32	.34	6.8	.61	"
15*	14.68	15.12	.46	.45	.036	.0047	.61	.47	6.7	.52	"
6	4.23	5.58	.62	.50	.127	.0123	.56	.60	6.9	.22	Trace blight
7*	15.49	4.31	.54	.49	.106	.0035	1.10	.27	7.0	.37	"
5	19.43	9.54	.48	.25	.095	.0035	.31	.36	6.5	.27	No blight
10	6.92	10.58	.42	.50	.100	.0176	.44	.45	6.6	.40	"
11*	7.25	7.52	.54	.37	.031	.0121	.49	.25	7.3	.34	"
13	15.01	12.22	.40	.39	.034	.0045	.32	.55	6.8	.36	"
16	10.45	13.53	.48	.47	.042	.0067	.55	.41	6.5	.52	"
17*	13.50	12.78	.60	.42	.030	.0046	.33	.62	7.2	.52	"

These analyses would be interpreted as all showing excellent fertility. Available lime and potash are good, as is also the phosphate in the surface soil. The phosphate results are significant in that there is an unusually large decrease in availability in going from the soil to the subsoil. In sampling these soils care was taken that none of the surface soil particles contaminated the subsoil. Since these analyses were made, Mr. Campsie, manager of Hawaiian Agricultural Company, is getting excellent response in many fields by applying superphosphate in the subsoil. This is accomplished by fertilizing in the furrow below the seed at planting time. The writer has noted further indication of the low availability of phosphate in the subsoil at Pahala in the scanty growth on some ridges where the surface soil has been washed off leaving the yellow subsoil exposed. Furthermore, crusher juice analyses recently submitted by Mr. Campsie are low in phosphate, also indicating a low assimilation. Emphasis is placed on this subsoil data because the Hawaiian Agricultural Company is an unirrigated plantation. With an annual rainfall of only 40-60 inches the roots must necessarily feed largely below the surface soil, which is very thin in this district. From the wide variation in soil and subsoil to lower Goodale and Stone fields, which are very bad blight fields, and less variation in Mudflow, Clover and Moaula, it was at first thought that this might have more than passing significance. Heavy phosphate applications have given some response, but only partial improvement in

* Subsoils.

All figures except moisture and organic are on water-free basis.

blighted cane. The comparative reaction of these soils is also of interest. In the blighted fields there is little or no difference in reaction between the soil and subsoil, while in the good fields there is notably less acidity in the subsoil as compared to the surface soil. On the whole, these plant food analyses lend little information which is indicative of a causal agent.

In view of the notable response to heavy stable manure, previously pointed out, and partial response to green manure crops, the question of comparative organic content of the soils arose. With this in mind a number of total nitrogen and carbon determinations were made. The carbon determinations are given in the following table while the nitrogen determinations are shown in Table 1:

TABLE 2

Carbon Content of Pahala Soils

	Per cent Carbon
Blight	
Lower Goodale	4.84
Lower Goodale subsoil	5.81
Lower Stone	4.89
Lower Naahala	4.02
Lower Aliona	4.67
Lower Whitney	4.89
Middle Whitney	4.92
Lower Moaula	6.66
Middle Naahala	6.60
Meyer	6.80
Mission	7.17
No Blight	
Upper Mudflow	6.19
Upper Stone	6.30
Upper Whitney	5.49
Upper Clover	6.83
Upper Naahala	5.88
Upper Moaula	8.02
Railroad	5.69
Mill	6.89
Clover	5.80
Middle Moaula	7.12

All are well supplied with organic matter. The average is slightly lower in the blighted fields, but it is believed that the average is more or less nullified by the variation. The total nitrogen content also has no special significance.

Soil Survey: Supplementing the above soil work, Stewart made an extensive soil survey of the plantation, determining the available and total plant foods. The chemical analyses indicated a high degree of fertility. It is significant that on the whole the soils from fields free from blight are slightly more acid than those from the blight fields, although there are variations from this. Other than this possible reaction relation the soil survey gave little information as to the causal factor or factors. In the samples collected in the soil survey there is also shown a greater variation in reaction between soil and subsoil in the sam-

ples from the blight fields. In the blight fields, out of 21 samples in 11 cases the subsoil is more alkaline than the top soil, 5 are less and in 5 cases there is no difference. This is compared with 27 samples from no blight areas in which only 7 samples had a less acid subsoil and the difference covered was far less than in the samples from blighted fields.

The average of the soil reaction data taken from Stewart's report is given in the following table:

	Average pH	Minimum pH	Maximum pH
Surface soil, no blight fields	6.61	6.1	7.3
Subsoil, no blight fields	6.60	6.0	7.3
Surface soil, blight fields	6.80	6.5	7.3
Subsoil, blight fields	6.90	6.3	7.5

Soil Solution: The soil solution was obtained from several representative soils by the displacement method, analyzed and used as a culture medium for the growth of cane shoots. The analyses are given in the following table:

TABLE 3

Composition of Soil Solution

Results Expressed in Parts per Million of Solution

	Lower Goodale Surface	(Blight) Subsoil	Wood Valley Surface	Mudflow Surface	Lower Surface	Aliona Subsoil
Total Solids	1820	842	1760	823	1832	960
Non Vol. Solids	1240	402	1042	528	....	...
Vol. Solids (organic)	580	440	718	295	....	...
Chlorine (Cl)	735	195	310	274	960	172
Nitrate Nitrogen (N)	7	.6	70	17	....	...
Iron and Al. Oxides	3	2	5	3	....	...
Silica (SiO_2)	28	20	47	20	....	...
Lime (CaO)	224	90	204	90	....	...
Sul. Triox. (SO_3)	24	22	30	4	....	...
Phos. Acid (P_2O_5)	1.3	.2	.7	.2	....	...
Magnesia (MgO)	120	49	123	52	....	...
Potash (K_2O)	58	18	74	142	....	...
Soda (Na_2O)	113	56	137	8	....	...

There is a notably high concentration of chlorine in the surface soil of the blight fields. This chlorine is combined as the chlorides of sodium, calcium and magnesium. While we find many irrigated soils higher in chlorine, it is believed that this figure is very high for an unirrigated plantation. At the same time the sulphates are very low.

Plant Cultures: In our investigations on the toxicity of various chemicals on sugar cane a method has been developed for growing cane shoots in water or sand cultures. In accomplishing this the seed pieces are planted in soil and after germination of the buds the shoots are grown to a height of about 8 inches. The shoot is then cut from the seed piece and suspended in water. In the course of a few days roots will develop at the base of the shoot and their vigor will

vary with the nature of the solution in which the shoot is growing. Using this method sufficient soil solution was removed from a blight field soil and subsoil and from the Mudflow field soil and subsoil and used as a medium in which to grow cane shoots.

The shoots were started in the soil solution cultures on January 21. On January 28 there was a marked difference in the appearance of the tops. At this time roots had appeared on all shoots. On February 4, two weeks after starting the shoots in the culture solutions, it was very apparent that some factor was retarding growth in the cultures from Lower Goodale field. The appearance of the plants at this time is shown in Fig. 2.

Chlorine: In view of the higher concentration of chlorine in the soil solution of the soil from blight fields as compared to those on which blight is absent, especially the Mudflow field, a number of samples from representative fields were selected and total chlorine determinations made. The results are given in the following table:

TABLE 4

Chlorine Content of Pahala Soils

Field	Per cent Chlorine	Field	Per cent Chlorine
Lower Goodale	.013	Upper Mudflow	.027
Lower Stone	.003	Upper Stone	.004
Lower Naahala	.003	Upper Whitney	.004
Lower Aliona	.002	Upper Clover	.039
Lower Whitney	.004	Upper Naahala	.050
Middle Whitney	.007	Upper Moaula	.031
Lower Moaula	.002	Railroad	.011
		Mill	.006

These results show a low chlorine content in all fields, but in most cases the total chlorine content of the good fields is higher than that from the blight fields.

Plant Analyses: In view of the fact that the D 1135 variety is notably resistant to blight and Yellow Caledonia is notably susceptible these two varieties were selected for a comparative study. A D 1135 planting may often give a count of 90-100 per cent blight in the early stages of growth and later grow out of it almost entirely. Thus the nature of this resistance in D 1135 was sought in the composition of the plant. The analyses included roots and juice from stalks where plants had reached sufficient age and leaves. In selecting the leaves, the five youngest leaves were taken from the stalk after discarding the rolled or zero leaf. This care was found to be necessary in view of the change in composition of the cane leaves on aging. Juice samples were obtained by pressure without any previous treatment of the stalks, such as freezing to break up the plant cells.

The composition of the leaves is given in Tables 5 and 6, the roots in Table 7, and the juices from the stalks in Table 8. On the whole, the ash is higher in

the blighted leaves and it is recognized that this may be a result as well as a cause. Comparing Yellow Caledonia and D 1135 the general tendency seems to be toward a higher calcium in the Caledonia variety. Comparing the two varieties growing in the same field Yellow Caledonia is higher in chlorides, calcium, magnesium and silica. Comparing, again, blighted and normal leaves it is significant that the young shoots are higher in chlorine than old shoots in the same stool and further that young shoots are often chlorotic in stools in which the large stalks are free from chlorotic leaves. The data as viewed in a general grouping as submitted in Table 5 shows wide variations.

In Table 6 the analyses have been tabulated to show the comparative composition of normal and blighted leaves taken from the same stools or from contiguous stools in the same field. Here, it will be noted, the comparative figures are more consistent. Higher ash, silica and chlorine, and in most cases higher potash, phosphate and nitrogen characterize the blighted leaves. The calcium and magnesium show a different ratio, that is, a higher ratio of magnesium to calcium in the blighted leaves.

The composition of the juice shows again a higher ash in the juice from blighted cane. The silica is lower, calcium and magnesium are lower as per cent of ash, sodium and chlorine are higher and phosphate lower.

The analyses of the roots show wide variations in both blighted and normal plants, and viewing the results as a whole the variations are too great to permit any deductions. On the other hand, on comparing the analyses of contiguous plants in the same field it will be noted that the higher chlorine in the roots from blighted plants is significant.

The question then arose as to the comparative composition of the chlorotic cane at Hawaiian Agricultural Company to that often observed on other plantations on other islands. With the cooperation of Mr. Kutsunai, who was at the time studying the value of sprays and dusts in the control of chlorosis, a number of soil, juice and leaf samples were obtained at Waialua and Ewa plantations.

The samples at Waialua were obtained from two mauka fields, in one of which the chlorosis was notably severe along the unlined irrigation ditches. The Ewa samples were from coral fields. Leaves in both cases showed the characteristic striping. The composition of the leaves and juices is given in Tables 9 and 10, and the soil analyses in Tables 11 and 12. In the latter, other than the reaction, all determinations were made on the soil solution as obtained by the displacement method.

The data on the Waialua plants shows a higher ash in the chlorotic leaves. The lime is higher in the juice from the stalks bearing chlorotic leaves. The same is true of chlorine. The plants from Ewa also show a higher ash in the chlorotic leaves.

TABLE 5

TABLE SHOWING COMPOSITION OF LEAVES, BLIGHTED AND NORMAL

Results Expressed as (1) Per Cent of Dry Matter, (2) Per Cent of Ash

	Date Sampled 1924-25	Ash	Silica SiO_2		Iron and Aluminum Fe_2O_3 & Al_2O_3		Lime CaO		Mag. MgO		Sodium Na_2O		Potash K_2O		Sulphates SO_3		Phos. Acid P_2O_5		Chlorine Cl	Total Nitrogen N
			1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	1
HEALTHY LEAVES — YELLOW CALEDONIA																				
Yellow Caledonia—Mill field—Near Camp below mill	Dec.	9.00	4.14	46.00	.01	.14	.36	4.08	.20	2.30	.12	1.30	2.63	29.30	.59	6.62	.43	4.85	.27	.74
Yellow Caledonia—Mill field—Near Camp below mill	Dec.	9.39	4.17	44.46	.10	1.10	.39	4.24	.25	2.67	.14	1.51	2.80	29.88	.62	6.69	.48	5.14	.27	.73
Yellow Caledonia—Mill field—Near Camp below mill	Dec.	9.71	4.14	42.66	.04	.50	.42	4.34	.23	2.36	.11	1.12	2.66	27.45	.54	5.61	.44	4.58	.27	.97
Yellow Caledonia—Mill field—Near Camp below mill	Feb.	6.86	1.03	15.09	..	..	.19	2.78	.18	2.75	.28	4.20	2.94	43.00	.54	7.93	.39	5.74	.39	1.18
Yellow Bamboo—Young shoot in old stool near Yellow Caledonia—Mill Field	Feb.	6.92	.97	14.01	.12	1.84	.20	2.92	.17	2.34	.28	4.20	3.10	44.80	.32	4.62	.38	5.55	.62	1.31
Yellow Caledonia—Kapapala field—Stools 16-18 months	Feb.	6.81	2.88	42.36	.08	1.22	.38	5.70	.30	4.48	.50	7.60	1.88	27.56	.37	5.46	.33	4.93	.51	.98
Yellow Caledonia—Wood Valley Field—Stand—18 months cane	Feb.	8.47	3.60	42.47	.09	1.13	.43	5.09	.37	4.37	.32	3.96	2.40	28.40	.34	4.08	.41	4.85	.71	1.25
Yellow Caledonia—Wood Valley Field—Young shoots from stools	Feb.	5.80	3.82	....	.17	2.93	.44	7.70	.42	7.36	..	...	...	....	.28	5.11	.44	7.67	.75	1.31
Yellow Caledonia—Mudflow—6 months plant	Feb.	10.14	4.80	47.42	.14	1.39	.54	5.41	.36	3.61	.30	2.90	2.48	24.58	.37	3.72	.42	4.16	.73	1.50
Yellow Caledonia—Mudflow—6 months plant—ratoon	Feb.	8.41	3.66	43.52	.05	.58	.50	5.94	.41	4.86	.40	4.80	2.24	26.66	.41	4.91	.42	5.04	.61	1.41
Yellow Caledonia—Lower Goodale—16 months	Feb.	8.99	4.16	46.28	..	..	.60	6.71	.39	4.42	.28	3.20	2.04	22.60	.47	5.23	.45	5.05	.43	1.43
Yellow Caledonia—Lower Goodale—16 months	Feb.	7.96	2.95	37.07	..	..	.53	6.72	.37	4.71	.30	3.80	2.22	27.88	.45	5.66	.49	6.19	.35	.84
Yellow Caledonia—Middle Moaula—6 months	Feb.	10.02	4.93	49.26	.14	1.41	.59	5.98	.34	3.47	.30	3.10	2.24	22.48	.36	3.62	.47	4.76	.42	1.83
Yellow Caledonia—Walker—8 months ratoons	Feb.	8.03	2.86	35.62	.09	1.17	.44	5.53	.31	3.88	.28	3.34	2.62	32.68	.34	4.28	.49	6.20	.44	1.45
Yellow Caledonia—Walker—8 months ratoons	Feb.	8.75	3.74	42.62	.19	2.13	.38	4.30	.24	2.70	.28	3.20	2.44	28.00	.31	3.56	.47	5.22	.34	1.78
HEALTHY LEAVES — D 1135																				
D 1135—Middle Naahala—(Yellow Caledonia badly blighted here)	Dec.	9.81	4.31	43.99	..	..	.35	3.64	.32	3.26	.13	1.31	2.83	28.89	.44	4.54	.43	4.43	.42	1.58
D 1135—Middle Naahala—(Yellow Caledonia badly blighted here)	Dec.	10.40	4.17	40.24	.05	.47	.26	2.58	.24	2.33	.07	.72	3.43	33.10	.45	4.42	.49	4.72	.42	1.58
D 1135—Lower Naahala—(Yellow Caledonia badly blighted here)	Dec.	9.81	...	....	.11	1.16	.33	3.40	.29	3.02	.07	.75	2.65	27.00	.48	4.92	.43	4.43	.42	1.78
D 1135—Lower Naahala—(Yellow Caledonia badly blighted here)	Dec.	8.68	4.33	49.94	.08	.92	.29	3.40	.32	3.74	..	...	2.30	26.54	.42	4.92	.51	5.90	.42	1.78
D 1135—Wood Valley	Feb.	7.80	2.97	37.99	.04	.51	.26	3.41	.20	2.61	.32	2.24	2.72	35.08	.27	4.86	.37	4.84	.76	...
D 1135—Wood Valley	Feb.	7.57	2.65	34.79	.02	.21	.25	6.71	.17	2.25	.28	3.86	2.72	36.16	.25	3.32	.44	5.87	.63	1.19
STRIPED LEAVES (SLIGHT BLIGHT)—YELLOW CALEDONIA																				
Yellow Caledonia—Lower Aliona—trace of blight	Dec.	9.29	4.06	43.76	.07	.77	.32	3.42	.23	2.54	.11	1.17	2.80	30.11	.37	3.96	.41	4.47	.30	1.19
Yellow Caledonia—Lower Aliona—trace of blight	Dec.	12.73	7.28	57.20	.13	1.02	.53	4.20	.29	2.33	.15	1.16	2.83	22.23	.54	4.30	.37	2.95	.30	1.19
Yellow Caledonia—Mill field—trace of blight	Dec.	10.64	4.46	41.98	..	..	.36	3.44	.28	2.69	.09	.83	3.34	31.40	.64	6.04	.51	4.85	.40	1.12
Yellow Caledonia—Mill field—trace of blight	Dec.	11.32	5.64	49.83	.12	1.05	.26	2.32	.21	1.90	..	...	...	....	.63	5.60	.51	4.51	.40	1.12
Yellow Caledonia—Mill field—trace of blight	Dec.	9.41	4.15	44.18	.04	.46	.34	3.60	.23	2.53	.12	1.26	2.83	30.06	.52	5.50	.46	4.95	.42	1.47
Yellow Caledonia—Kapapala—trace of blight	Feb.	11.36	5.92	52.13	.18	1.58	.55	4.85	.37	3.30	.32	2.90	.65	23.20	.56	4.96	.43	3.83	.59	1.30
STRIPED LEAVES — D 1135																				
D 1135—Middle Naahala—trace of blight	Dec.	10.12	4.18	41.30	.04	.40	.22	2.24	.23	2.29	.15	1.49	3.46	34.24	.50	5.00	.47	4.65	..	1.48
D 1135—Middle Naahala—trace of blight	Dec.	10.26	4.11	40.06	.14	1.35	.23	2.26	.25	2.52	.09	.95	3.31	32.25	.43	4.24	.46	4.54	..	1.48
D 1135—Wood Valley	Feb.	6.97	2.04	....	.18	2.56	.18	5.10	.19	2.78	.44	6.30	2.88	41.20	.26	3.73	.35	5.07	.49	1.29
BADLY BLIGHTED LEAVES — YELLOW CALEDONIA																				
Yellow Caledonia—Middle Naahala	Dec.	11.12	5.07	45.56	..	..	.33	3.02	.34	3.12	.15	1.36	3.02	27.15	.45	4.08	.63	5.67	.52	...
Yellow Caledonia—Middle Naahala	Dec.	13.24	5.89	44.53	.08	.66	.34	2.64	.23	1.80	.23	1.75	3.55	26.86	.55	4.20	.61	4.62	.52	...
Yellow Caledonia—Lower Aliona	Dec.	15.25	8.73	57.26	.30	2.00	.50	3.32	.39	2.61	.03	.19	3.45	22.66	.64	4.26	.58	5.81	.51	.91
Yellow Caledonia—Lower Aliona	Dec.	13.56	6.54	49.01	.13	1.00	.30	2.24	.37	2.81	.13	1.01	3.48	26.11	.62	4.70	.62	4.79	.40	.90
Yellow Caledonia—Lower Aliona	Dec.	12.00	5.39	44.95	.24	2.00	.24	2.02	.31	2.62	.10	.87	3.51	29.30	.52	4.76	.62	5.18	.40	.91
Yellow Caledonia—Mudflow (edge field)	Feb.	14.84	6.04	40.74	.17	1.15	.45	3.04	.34	2.30	.34	2.20	...	....	.39	2.64	.44	3.08	.61	1.46
Yellow Caledonia—Lower Goodale	Feb.	7.97	3.01	37.84	.04	.56	.29	3.75	.31	4.00	.30	3.96	...	....	.38	4.88	..	...	.47	1.77
Yellow Caledonia—Lower Goodale	Feb.	9.58	3.67	38.36	..	..	.44	4.68	.48	5.10	.42	4.42	2.82	29.60	.45	4.76	.62	6.50	.53	1.71
Yellow Caledonia—Walker—ratoon	Feb.	10.67	4.86	45.59	.	..	.34	3.26	.40	3.79	.20	1.92	2.80	26.30	.36	3.37	.65	6.08	.46	1.67
Yellow Caledonia—Walker—ratoon	Feb.	11.05	5.28	47.86	.32	.58	.59	5.42	.45	4.12	.36	3.26	2.50	22.70	.37	3.37	.71	4.63	.51	1.77
Yellow Caledonia—Middle Naahala	Feb.	12.12	5.72	47.31	..	..	.46	3.84	.40	3.30	.40	3.20	3.00	24.50	.51	4.23	.70	5.81	.46	1.97
Yellow Caledonia—Lower Aliona	Feb.	11.05	5.15	46.60	..	..	.44	4.02	.39	3.56	.34	3.00	2.84	25.60	.32	1.44	.64	5.79	.49	1.95

TABLE 6

TABLE COMPARING COMPOSITION OF NORMAL AND BLIGHTED LEAVES TAKEN FROM CONTIGUOUS PLANTS IN THE SAME FIELDS

Results Expressed as (1) Per Cent Dry Matter and (2) Per Cent Ash

	Date Sampled 1924-25	Ash	Silica SiO_2		Iron and Aluminum Fe_2O_3 & Al_2O_3		Lime CaO		Mag. MgO		Sodium Na_2O		Potash K_2O		Sulphates SO_3		Phos. Acid P_2O_5		Chlorine Cl	Nitrogen N
			1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	1
Yellow Caledonia—Mill field—Healthy leaves	Dec.	9.00	4.14	46.00	.01	.14	.36	4.08	.20	2.30	.12	1.30	2.63	29.30	.59	6.62	.43	4.85	.27	.74
Yellow Caledonia—Mill field—Healthy leaves	Dec.	9.39	4.17	44.46	.10	1.10	.39	4.24	.25	2.67	.14	1.51	2.80	29.88	.62	6.60	.48	5.14	.27	.73
Yellow Caledonia—Mill field—Healthy leaves	Dec.	9.71	4.14	42.66	.04	.50	.42	4.34	.23	2.36	.11	1.12	2.66	27.45	.54	5.61	.44	4.58	.27	.97
Yellow Caledonia—Mill field—Healthy leaves	Feb.	6.86	1.03	15.09	..	..	.19	2.78	.18	2.75	.28	4.20	2.94	43.00	.54	7.93	.39	5.74	.39	1.18
Yellow Caledonia—Mill field—Slight blight leaves	Dec.	10.64	4.46	41.98	..	..	.36	3.44	.28	2.69	.09	.83	3.34	31.40	.64	6.04	.51	4.85	.40	1.12
Yellow Caledonia—Mill field—Slight blight leaves	Dec.	11.32	5.64	49.83	.12	1.05	.26	2.32	.21	1.90	..	..	...	....	.63	5.60	.51	4.51	.40	1.12
Yellow Caledonia—Mill field—Slight blight leaves	Dec.	9.41	4.15	44.18	.04	.46	.34	3.60	.23	2.53	.12	1.26	2.83	30.06	.52	5.50	.46	4.95	.42	1.47
Yellow Caledonia—Kapapala—Healthy leaves	Feb.	6.81	2.88	42.36	.08	1.22	.38	5.70	.30	4.48	.50	7.60	1.88	27.56	.37	5.46	.33	4.93	.51	.98
Yellow Caledonia—Kapapala—Slight blight	Feb.	11.36	5.92	52.13	.18	1.58	.55	4.85	.37	3.30	.22	2.90	2.62	23.20	.56	4.96	.43	3.83	.59	1.30
Yellow Caledonia—Edge Mudflow—Healthy leaves	Feb.	10.14	4.80	47.42	.14	1.39	.54	5.41	.36	3.61	.30	2.90	2.48	24.58	.37	3.72	.42	4.16	.73	1.50
Yellow Caledonia—Edge Mudflow—Healthy leaves	Feb.	8.41	3.66	43.52	.05	.58	.50	5.94	.41	4.86	.40	4.80	2.24	26.66	.41	4.91	.42	5.04	.61	1.41
Yellow Caledonia—Edge Mudflow—Bad blight	Feb.	14.84	6.04	40.74	.17	1.15	.45	3.04	.34	2.30	.34	2.20	...	...	.29	2.64	.44	3.02	.61	1.46
Yellow Caledonia—Lower Goodale—Healthy leaves	Feb.	8.99	4.16	46.28	..	..	.60	6.71	.39	4.42	.28	3.20	2.04	22.60	.47	5.23	.45	5.05	.43	1.43
Yellow Caledonia—Lower Goodale—Healthy leaves	Feb.	7.96	2.95	37.07	..	..	.53	6.72	.37	4.71	.30	3.80	2.22	27.88	.45	5.66	.49	6.19	.35	.84
Yellow Caledonia—Lower Goodale—Bad blight	Feb.	7.97	3.01	37.84	.04	.56	.29	3.75	.31	4.00	.30	3.96	...	...	.38	4.88	..	...	.47	1.77
Yellow Caledonia—Lower Goodale—Bad blight	Feb.	9.58	3.67	38.36	..	..	.44	4.68	.48	5.10	.42	4.42	2.82	29.60	.45	4.76	.62	6.50	.53	1.74
Yellow Caledonia—Walker—Healthy leaves	Feb.	8.03	2.86	35.62	.09	1.17	.44	5.53	.31	3.88	.28	3.34	2.62	32.68	.34	4.28	.49	6.20	.33	1.45
Yellow Caledonia—Walker—Healthy leaves	Feb.	8.75	3.74	42.62	.19	2.13	.38	4.30	.24	2.70	.28	2.20	2.44	28.00	.31	3.56	.47	5.22	.34	1.58
Yellow Caledonia—Walker—Bad blight	Feb.	10.67	4.86	45.59	..	..	.34	3.26	.40	3.79	.20	1.92	2.80	26.30	.36	3.37	.65	6.08	.46	1.67
Yellow Caledonia—Walker—Bad blight	Feb.	11.05	5.28	47.86	.32	.58	.59	5.42	.45	4.12	.36	3.26	2.50	23.70	.37	3.37	.71	4.63	.51	1.77
Yellow Caledonia—Lower Aliona—Trace blight	Dec.	9.29	4.06	43.76	.07	.77	.32	3.42	.23	2.54	.11	1.17	2.80	30.11	.37	3.96	.41	4.47	.30	1.19
Yellow Caledonia—Lower Aliona—Trace blight	Dec.*	12.73	7.28	57.20	.13	1.02	.53	4.20	.29	2.33	.15	1.16	2.83	22.23	.74	4.50	.37	2.95	.30	1.19
Yellow Caledonia—Lower Aliona—Bad blight	Dec.	15.25	8.73	57.26	.30	2.00	.50	3.32	.39	2.61	.03	.19	3.45	22.66	.64	4.26	.58	3.81	.50	.90
Yellow Caledonia—Lower Aliona—Bad blight	Dec.	13.36	6.54	49.01	.13	1.00	.30	2.24	.37	2.81	.13	1.01	3.48	26.11	.62	4.70	.62	4.70	.40	.90
Yellow Caledonia—Lower Aliona—Bad blight	Dec.	12.00	5.39	44.95	.24	2.00	.24	2.02	.31	2.62	.10	.87	3.51	29.30	.52	4.36	.62	5.18	.40	.90
Yellow Caledonia—Lower Aliona—Bad blight	Feb.	11.05	5.15	46.60	..	..	.44	4.02	.39	3.56	.34	3.09	2.84	25.66	.32	1.44	.64	5.79	.49	1.95
Yellow Caledonia—Near Aliona—Middle Naahala—Bad blight	Dec.	11.12	5.07	45.56	..	..	.33	3.02	.34	3.12	.15	1.36	3.02	27.15	.45	4.08	.63	5.67	.52	...
Yellow Caledonia—Near Aliona—Middle Naahala—Bad blight	Dec.	13.24	5.89	44.53	.08	.66	.34	2.64	.23	1.80	.24	1.75	3.55	26.86	.55	4.20	.61	4.62	.52	..
Yellow Caledonia—Near Aliona—Middle Naahala—Bad blight	Feb.	12.12	5.72	47.31	..	..	.46	3.84	.40	3.30	.40	3.20	3.00	24.70	.51	4.23	.70	5.81	.46	1.97

TABLE 7

TABLE SHOWING COMPOSITION OF ROOTS FROM BLIGHTED AND NORMAL PLANTS

Results Expressed as (1) Per Cent Dry Matter, (2) Per Cent Ash

	Ash	Silica SiO_2		Iron and Aluminum Oxides Al_2O_3 & Fe_2O_3		Lime CaO		Magnesia MgO		Sulphates SO_3		Phos. Acid P_2O_5		Chlorine Cl		Sodium Na_2O		Potash K_2O		Nitrogen N
		1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1
1. Yellow Caledonia—Kapapala ratoons—some stripes—18 months—no blight.	19.33	7.84	40.56	4.83	25.55	1.33	6.88	0.96	4.97	1.24	6.42	0.23	1.20	.022	.105	0.19	1.01	0.12	0.70	0.74
2. Yellow Caledonia—Wood Valley—ratoons—18 months—no blight..........	36.78	14.41	39.18	13.44	36.56	0.76	4.29	0.95	2.59	0.28	0.77	0.24	0.65	.014	.079	0.20	0.55	0.09	0.25	0.62
3. Yellow Caledonia—Mudflow—plant—6 months—no blight................	30.98	12.41	40.10	9.85	31.84	1.51	3.71	0.98	3.17	0.28	0.89	0.36	1.16	.031	.101	0.30	0.99	0.16	0.52	...
5. Yellow Caledonia—Mudflow—ratoon—no blight.........................	11.73	4.85	41.29	3.49	29.80	0.58	4.91	0.46	3.90	0.29	2.46	0.22	1.89	.029	.246	0.20	1.60	0.15	1.25	0.90
6. Yellow Caledonia—Mill—plant—18 months—no blight	16.07	6.20	38.92	4.32	27.10	0.85	5.36	0.61	3.85	0.37	2.32	0.34	2.15	.015	.090	0.16	0.99	0.17	1.10	1.42
7. Yellow Caledonia—Mill—plant—18 months—no blight	23.95	9.91	41.37	7.46	31.15	0.92	3.85	0.68	2.84	0.32	1.35	0.70	2.94	.030	.124	0.17	0.70	0.30	1.28	0.95
8. Yellow Caledonia—Middle Moaula—plant—6 months—no blight..........	18.07	6.07	33.58	6.87	38.03	0.59	3.30	0.61	3.38	0.29	1.61	0.30	1.70	.041	.226	0.20	1.09	0.22	1.20	1.14
9. Yellow Caledonia—Walker—ratoon—no blight	25.54	10.58	41.40	6.94	27.20	1.33	5.20	0.80	3.13	0.32	1.23	0.46	1.82	.046	.185	0.14	0.91	0.20	0.79	...
4. Yellow Caledonia—Edge of Mudflow—plant—blight..	29.70	11.04	37.18	10.07	33.90	0.98	3.29	1.01	3.40	0.33	1.10	0.26	0.88	.044	.149	0.29	0.96	0.25	0.82	0.79
10. Yellow Caledonia—Walker ratoon—blight...........	11.68	4.99	42.72	2.29	19.54	0.69	5.91	0.47	4.01	0.46	3.98	0.36	3.08	.050	.431	0.24	0.21	0.24	0.21	...
11. Yellow Caledonia—Middle Naahala—plant—blight.......................	18.29	6.64	36.36	5.17	28.26	0.80	4.40	0.70	3.83	0.37	2.06	0.36	1.96	.078	[illegible]	[illegible]	[illegible]	0.33	1.79	...
12. Yellow Caledonia—Lower Aliona—plant—blight	34.87	5.59	....	3.39	....	0.71	2.02	0.51	1.46	0.35	1.00	0.32	0.91	.037	.107	0.20	0.55	0.18	0.53	..

TABLE 8

TABLE COMPARING COMPOSITION OF JUICE FROM GOOD AND BLIGHTED YELLOW CALEDONIA

Results Expressed as (1) Parts per Mil. in Juice, (2) Per Cent of Ash

	Ash	Silica SiO_2		Lime CaO		Mag. MgO		Sodium Na_2O		Potash K_2O		Sulphates SO_3		Phos. Acid P_2O_5		Chlorine Cl		Brix
		1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1
Lower Aliona—Yellow Caledonia—blight cane..............................	414	10	2.50	21	5.26	35	8.50	24	5.84	154	37.30	54	13.14	25	6.25	62	15.03	10.73
Lower Aliona—Yellow Caledonia—good cane...............................	356	12	3.53	20	5.79	33	9.44	19	5.44	122	34.32	51	14.44	37	10.40	30	8.60	13.33
Lower Goodale—Yellow Caledonia—blight cane..............................	612	15	2.60	5	.91	17	2.80	35	5.70	...	....	74	12.20	80	13.17	93	15.30	15.00
Lower Goodale—Yellow Caledonia—good cane	387	16	4.18	38	10.00	50	13.08	29	7.70	76	19.64	.	....	89	23.10	25	6.61	18.00
Lower Aliona—Yellow Caledonia—blight cane...............................	474	11	2.48	33	7.12	49	10.40	23	5.01	...	....	84	17.82	29	6.13	76	[illegible]	13.40
Lower Aliona—Yellow Caledonia—good cane	304	18	5.92	25	8.42	46	15.20	12	6.97	...	....	.	....	48	15.99	68	22.37	14.90
Makiki Plots Experiment Station—Yellow Caledonia—good cane.............	643	26	4.10	22	3.63	47	7.36	28	4.41		. .	6	9.63	97	15.15	[illegible]	[illegible]	16.80
Manoa Substation—Yellow Caledonia—good cane.............................	609	14	2.29	22	3.57	60	9.84	33	5.38	190	31.26	19	30.83	40	6.56	45	7.41	19.70

TABLE 9

TABLE SHOWING COMPARATIVE COMPOSITION OF LEAVES AND JUICES FROM CHLOROTIC AND GREEN CANE FROM WAIALUA AGRICULTURAL COMPANY

Expressed as Per Cent Dry Matter

Description of Sample	Brix of Juice	Sample No.	Ash	Silica SiO_2	Iron Fe_2O_3	Lime CaO	Magnesia MgO	Soda Na_2O	Potash K_2O	Sulphur Trioxide SO_3	Phos. Acid P_2O_5	Chlorine Cl
Leaves H 109, Opaeula, chlorotic, ratoons	....	17	11.01	2.87	.22	.37	.31	.30	3.95	1.03	.49	1.28
Leaves H 109, Opaeula, chlorotic, ratoons	....	18	12.75	3.78	.28	.40	.35	.25	4.25	1.12	.79	1.09
Leaves H 109, Opaeula, green, ratoons	....	19	7.54	2.77	.16	.31	.31	.22	2.07	.58	.56	.69
Leaves H 109, Opaeula, green, ratoons	....	20	8.17	3.03	.13	.37	.30	.22	2.24	.66	.62	.55
Leaves H 109, Opaeula, chlorotic, ratoons	....	21	14.54	6.02	.13	.34	.47	.19	3.91	.86	.90	.74
Leaves H 109, Opaeula, chlorotic, ratoons	....	22	14.58	6.51	.21	.49	.52	.21	3.44	.91	.84	1.30
Leaves H 109, Opaeula, green, ratoons	....	23	8.26	3.14	.08	.43	.44	.25	2.04	.67	.56	.67
Leaves H 109, Opaeula, green, ratoons	....	24	8.72	2.18	.08	.25	.33	.21	2.16	.53	.54	.79
Leaves H 109, Kawailoa, green	....	25	8.72	3.65	.11	.31	.35	.19	2.34	.43	.50	.51
Leaves H 109, Kawailoa, chlorotic } Same stool	....	26	8.49	4.15	.08	.30	.34	.23	2.13	.40	.46	.49
Juice H 109, Kawailoa, green	12.95	29	395*	22*	..	17*	..	..	...	54*	31*	97*
Juice H 109, Kawailoa, chlorotic	....	30	537*	15*	..	24*	62*	33*	195*	80*	47*	139*
Leaves H 109, Kawailoa, chlorotic	....	27	6.46	1.44	.13	.23	.27	.43	2.41	.38	.39	.51
Leaves H 109, Kawailoa, green } Same stool	....	28	5.85	1.15	.07	.27	.27	.25	2.32	.37	.43	.44
Juice H 109, Kawailoa, chlorotic	12.05	31	377*	9*	..	25*	48*	41*	146*	64*	14*	108*
Juice H 109, Kawailoa, green	10.40	32	546*	9*	..	18*	35*	33*	257*	40*	22*	127*
Leaves H 109, Kawailoa, chlorotic	....	33	7.85	2.59	.10	.33	.35	.29	2.85	.41	.46	.43
Leaves H 109, Kawailoa, chlorotic	....	35	8.55	3.13	.15	.22	.29	.23	2.99	.48	.55	.47
Leaves H 109, Kawailoa, chlorotic	....	37	7.98	2.55	.16	.28	.30	.28	2.79	.40	.43	.54
Leaves H 109, Kawailoa, green	....	39	6.44	1.99	.08	.25	.23	.21	2.41	.40	.38	.41
Leaves H 109, Kawailoa, green	....	41	5.95	1.48	.11	.23	.20	.22	2.30	.37	.44	.41
Juice H 109, Kawailoa, chlorotic	12.40	34	413*	17*	..	20*	40*	23*	212*	80*	28*	100*
Juice H 109, Kawailoa, chlorotic	9.80	36	511*	18*	..	16*	41*	19*	201*	70*	35*	109*
Juice H 109, Kawailoa, chlorotic	12.60	38	489*	12*	..	21*	50*	24*	172*	75*	26*	116*
Juice H 109, Kawailoa, green	9.75	40	579*	14*	..	12*	19*	16*	266*	40*	27*	108*
Juice H 109, Kawailoa, green	11.50	42	568*	12*	..	14*	28*	..	184*	49*	12*	107*

Expressed as Per Cent of Ash

Description of Sample	Silica SiO_2	Lime CaO	Magnesia MgO	Soda Na_2O	Potash K_2O	Sulphur Trioxide SO_3	Phos. Acid P_2O_5	Chlorine Cl
Leaves H 109, Opaeula, chlorotic, ratoons	26.14	3.40	2.84	2.71	35.93	9.34	4.49	12.01
Leaves H 109, Opaeula, chlorotic, ratoons	29.63	3.17	2.73	1.93	33.29	8.76	6.25	8.87
Leaves H 109, Opaeula, green, ratoons	36.82	4.15	4.17	2.96	27.53	7.74	7.41	8.09
Leaves H 109, Opaeula, green, ratoons	37.02	4.32	3.66	2.80	27.42	8.04	7.75	6.90
Leaves H 109, Opaeula, chlorotic, ratoons	41.40	2.36	3.24	1.35	26.85	5.93	6.20	5.11
Leaves H 109, Opaeula, chlorotic, ratoons	44.70	3.38	3.60	1.49	23.60	6.27	5.78	8.75
Leaves H 109, Opaeula, green, ratoons	38.05	5.22	5.40	3.04	24.74	8.16	6.80	7.91
Leaves H 109, Opaeula, green, ratoons	31.21	3.71	4.76	5.08	31.04	7.66	7.80	11.37
Leaves H 109, Kawailoa, green	41.88	3.59	4.04	2.21	26.87	5.02	5.82	5.99
Leaves H 109, Kawailoa, chlorotic } Same stool	48.91	3.57	4.03	2.79	25.10	4.78	5.45	5.95
Juice H 109, Kawailoa, green	5.67	4.30	...	...	...	13.66	7.89	24.70
Juice H 109, Kawailoa, chlorotic	2.90	4.54	11.54	6.25	36.40	15.07	8.82	25.98
Leaves H 109, Kawailoa, chlorotic	22.32	5.13	4.25	6.66	37.32	5.90	6.15	8.08
Leaves H 109, Kawailoa, green } Same stool	19.73	4.75	4.68	4.30	39.81	6.34	7.46	7.53
Juice H 109, Kawailoa, chlorotic	2.33	6.68	12.80	10.97	38.81	17.20	3.82	28.73
Juice H 109, Kawailoa, green	1.68	3.33	6.41	6.12	47.09	7.51	3.99	23.56
Leaves H 109, Kawailoa, chlorotic	33.00	4.22	4.45	3.75	36.36	5.29	5.89	5.63
Leaves H 109, Kawailoa, chlorotic	36.63	2.57	3.42	2.76	[illegible]	5.62	6.49	5.72
Leaves H 109, Kawailoa, chlorotic	31.93	3.55	3.75	3.58	[illegible]	5.07	7.46	6.83
Leaves H 109, Kawailoa, green	30.96	3.86	3.61	3.70	37.49	6.21	6.03	6.40
Leaves H 109, Kawailoa, green	24.86	3.91	3.34	3.08	28.76	6.90	7.50	6.48
Juice H 109, Kawailoa, chlorotic	4.11	4.89	9.68	5.56	51.35	19.60	6.81	24.50
Juice H 109, Kawailoa, chlorotic	3.68	3.29	8.10	2.83	39.48	17.69	6.96	21.44
Juice H 109, Kawailoa, chlorotic	2.45	4.46	10.50	4.97	[illegible]	15.34	5.44	23.87
Juice H 109, Kawailoa, green	4.21	2.14	[illegible]	2.73	[illegible]	[illegible]	4.73	18.70
Juice H 109, Kawailoa, green	2.11	2.46	5.06	...	[illegible]	[illegible]	2.11	18.80

* Expressed as milligrams per 100 cc. of juice.

TABLE 10

TABLE SHOWING COMPARATIVE COMPOSITION OF LEAVES AND JUICE FROM CHLOROTIC AND GREEN CANE FROM EWA PLANTATION COMPANY

Expressed as Per Cent Dry Matter

Description of Sample	Brix of Juice	Sample No.	Ash	Silica SiO_2	Iron Fe_2O_3	Lime CaO	Magnesia MgO	Soda Na_2O	Potash K_2O	Sulphur Trioxide SO_3	Phos. Acid P_2O_5	Chlorine Cl
Leaves H 109, 6 months, ratoon, chlorotic, Field 19c	....	47	9.82	3.82	.26	.35	.38	.24	2.98	.45	.48	.97
Leaves H 109, 6 months, ratoon, chlorotic, Field 19c	....	48	10.28	4.06	.22	.28	.45	..	...	.60	.61	1.17
Leaves H 109, 6 months, ratoon, green, Field 19c	....	49	7.72	3.14	.10	.42	.49	.29	1.95	.34	.42	1.05
Leaves H 109, 6 months, ratoon, green, Field 19c	....	50	7.22	3.00	.14	.34	.34	.25	1.96	.43	.44	1.30
Leaves H 109, large cane, chlorotic, Field 9	....	51	12.11	5.20	.16	.31	.38	.25	3.70	.51	.56	1.21
Leaves H 109, large cane, chlorotic, Field 9	....	53	13.75	3.80	..	.34	.40	..	4.24	.47	1.20	1.83
Leaves H 109, large cane, green, Field 9	....	55	7.50	2.62	.19	.27	.31	.24	2.25	.36	.50	.80
Leaves H 109, large cane, green, Field 9	....	57	8.28	3.81	.20	.26	.26	.28	2.17	.32	.46	.72
Leaves H 109, large cane, green, Field 9	....	59	6.22	1.20	.17	.31	.29	.36	2.22	.29	.51	1.14
Juice H 109, large cane, chlorotic, Field 9	7.0	52	547*	13*	..	16*	47*	25*	226*	108*	38*	177*
Juice H 109, large cane, chlorotic, Field 9	5.8	54	626*	14*	..	14*	38*	14*	312*	50*	49*	236*
Juice H 109, large cane, green, Field 9	17.2	56	287*	15*	..	14*	31*	17*	175*	36*	38*	150*
Juice H 109, large cane, green, Field 9	13.6	58	682*	24*	..	20*	51*	19*	173*	93*	49*	141*
Juice H 109, large cane, green, Field 9	19.2	60	701*	11*	..	17*	50*	39*	237*	43*	51*	258*

Expressed as Per Cent of Ash

Description of Sample	Silica SiO_2	Lime CaO	Magnesia MgO	Soda Na_2O	Potash K_2O	Sulphur Trioxide SO_2	Phos. Acid P_2O_5	Chlorine Cl
Leaves H 109, 6 months, ratoon, chlorotic, Field 19c	38.80	3.63	3.86	2.44	30.36	4.56	4.94	9.86
Leaves H 109, 6 months, ratoon, chlorotic, Field 19c	39.47	2.71	4.33	...	...	5.78	5.97	11.40
Leaves H 109, 6 months, ratoon, green, Field 19c	40.60	5.41	6.36	3.65	25.22	4.44	5.52	13.58
Leaves H 109, 6 months, ratoon, green, Field 19c	41.03	4.70	4.76	3.50	27.14	5.95	6.10	18.05
Leaves H 109, large cane, chlorotic, Field 9	42.92	2.58	3.11	2.09	30.50	4.21	4.60	10.00
Leaves H 109, large cane, chlorotic, Field 9	27.34	2.43	2.91	...	30.81	3.41	8.40	13.31
Leaves H 109, large cane, green, Field 9	35.00	3.66	4.18	3.22	[illegible]	4.83	6.59	10.67
Leaves H 109, large cane, green, Field 9	46.10	3.14	3.04	[illegible]	26.20	3.84	5.51	8.77
Leaves H 109, large cane, green, Field 9	19.10	4.97	4.65	5.75	[illegible]	4.71	8.17	18.25
Juice H 109, large cane, chlorotic, Field 9	2.30	2.92	8.18	4.29	[illegible]	18.65	6.69	15.41
Juice H 109, large cane, chlorotic, Field 9	2.27	2.30	6.16	2.27	49.92	8.04	7.90	18.84
Juice H 109, large cane, green, Field 9	3.97	3.61	8.11	4.45	45.70	9.45	9.86	19.47
Juice H 109, large cane, green, Field 9	3.51	2.93	7.79	2.78	...	13.71	7.26	10.37
Juice H 109, large cane, green, Field 9	1.56	2.54	7.12	5.61	48.45	[illegible]	7.26	18.44

* Expressed as milligrams per 100 cc. juice.

TABLE 11

TABLE SHOWING COMPOSITION OF THE SOIL MOISTURE IN WHICH ROOTS ARE GROWING, COMPARING GREEN AND CHLOROTIC CANE

Waialua Agricultural Company

Field	Leaves	Moisture Per cent in Soil	Reaction of Soil pH	Composition of the Soil Solution in Parts per Million of Solution: Total Solids	Silica SiO_2	Lime CaO	Magnesia MgO	Sodium Na_2O	Potash K_2O	Carbonate CO_3	Bicarbonate HCO_3	Chlorine Cl	Sulphur Trioxide SO_3
Opaeula 1	Chlorotic	12.6	8.27	2386	24	364	127	220	112	trace	148	112	500
Opaeula 2	Green	23.6	8.03	1610	10	183	74	225	21	none	72	336	134
Opaeula 3	Chlorotic	28.2	7.59	930	18	89	89	149	21	none	30	280	104
Opaeula 4	Green	26.8	7.25	808	36	63	68	104	48	none	30	202	94
Kawailoa 1	Chlorotic	25.8	8.86	1318	30	78	73	387	23	trace	94	514	122
Kawailoa 2	Green	23.8	8.60	1104	20	79	46	333	32	trace	86	386	108

TABLE 12

TABLE SHOWING COMPOSITION OF SOIL SOLUTION IN WHICH ROOTS WERE GROWING, COMPARING GREEN AND CHLOROTIC CANE

Ewa Plantation Company

Field	Leaves	Moisture Per cent in Soil	Reaction of Soil pH	Composition of Soil Solution in Parts per Million of Solution: Total Solids	Silica SiO_2	Lime CaO	Magnesia MgO	Sodium Na_2O	Potash K_2O	Carbonate CO_3	Bicarbonate HCO_3	Chlorine Cl	Sulphur Trioxide SO_3
19 c-1	Green	18.6	8.43	9288	50	833	689	1532	68	none	96	3502	640
19 c-2	Chlorotic	20.6	8.43	7970	60	770	547	1104	76	none	62	3254	544
9-1	Green	20.0	7.84	50732	1219	5280	4796	7094	144	none	48	22332	1528
9-2	Chlorotic	24.2	8.50	3948	74	385	155	514	44	none	62	1666	292

All soil analyses show a greater alkalinity where the cane is chlorotic. The concentration of soluble material in the soil solution does not appear to be a factor. A comparison of the total inorganic solids in which the Ewa cane is growing in a soil solution containing approximately 50,000 parts per million solids and the Waialua plants grown in 900-2,300 parts per million is of interest in that there is little difference in the inorganic solids in the cane juice.

Additional relative data is given in Table 13, showing comparative analyses of chlorotic and green shoots from Uba cane grown on the Makiki plots of the Experiment Station. In each case chlorotic and green leaves were taken from

the same stool which had been ratooning just three months. The shoots were about two feet in height and the cane soon after grew out of the chlorosis. These shoots had the characteristic leaf striping, but would be classed as only temporarily chlorotic in distinction to the permanent form which often persists throughout the life of the plant.

It will be seen that there is little difference in these analyses other than the slightly larger amount of chlorine in the chlorotic leaves and this may explain why these plants are only temporarily chlorotic.

As bearing further upon the question of the chloride content of the leaves as well as that of the soil solutions, a set of samples was obtained from Waianae plantation. This information was sought for comparative composition of plants grown on soils in which the soil solution is high in chlorides. The analyses of leaves and juice are given in the following Table 14. In no case was any chlorosis present on these leaves at time of sampling.

Relation of Rainfall and Irrigation

The higher concentration of salts in the soil solution from blight fields as compared to the low concentration in that from the Mudflow field suggested an irrigation test to see if changing the concentration or nature of the soil solution would have a favorable effect on the condition of the cane. This was further suggested by an examination of the rainfall records at Pahala (Figs. 10 and 11). The accompanying graphs were obtained from the plantation and show that in the Wood Valley district, where the cane is less seriously affected by the blight, the rainfall is greater than in the Pahala district where the blight is more severe. Added to this is the greater rainfall in the mauka fields where there is little or no blight. Having no water available for a field experiment this experiment was conducted in tubs.

In a preliminary experiment two stumps of Yellow Caledonia blighted cane were brought from Lower Aliona field, Pahala, to Honolulu and planted in (1) soil from Lower Aliona and (2) in Makiki Experiment Station soil. These plants were brought to Honolulu in November, 1924. They were watered three times a week and in ten days many shoots, all blighted, had developed from both stumps. In one month's time, after planting, all the leaves on the plant growing in Makiki soil had recovered and had developed a normal green color. The conclusion is evident that as soon as the new roots, developed from the old stubble, had started to feed upon the Makiki soil some disturbing factor was corrected or eliminated.

Beginning February 13 the Lower Aliona pot was watered daily. There being no change in the chlorotic stripes on the leaves up to March 23, the amount of water added was increased sufficiently to give a daily leaching out the bottom of the pot. On May 26, two months later, the leaves had practically all recovered from the chlorosis, but the plant was greatly stunted as compared to that growing in the Makiki soil.

A more complete experiment was then planned and conducted by Mr. Thompson at Pahala. Tubs holding 30 pounds of soil were used. Two series of pots were included, one of which was planted with Yellow Caledonia seed and the

TABLE 13

TABLE SHOWING PARTIAL ANALYSES OF GOOD AND CHLOROTIC LEAVES FROM UBA CANE GROWN ON MAKIKI PLOTS, EXPERIMENT STATION, H. S. P. A.*

Results Expressed as (1) Per Cent Dry Matter, (2) Per Cent Ash

	Ash	Silica SiO_2		Lime CaO		Mag. MgO		Sulphates SO_3		Phos. Acid P_2O_5		Chlorine Cl	
		1	2	1	2	1	2	1	2	1	2	1	2
Uba young ratoons—chlorotic leaves } Same stool	14.10	4.70	33.40	.63	4.47	.42	3.00	.59	4.16	.81	5.75	.17	1.23
Uba young ratoons—good leaves } Same stool	12.47	3.88	31.10	.50	3.99	.35	2.85	.53	4.23	.80	6.90	.13	1.02
Uba young ratoons—chlorotic leaves } Same stool	12.39	3.48	28.06	.54	4.33	.33	2.70	.55	4.50	.70	5.62	.16	1.36
Uba young ratoons—good leaves } Same stool	14.60	6.13	42.02	.64	4.40	.44	3.00	.81	5.53	.79	5.40	.13	1.00
Uba young ratoons—chlorotic leaves } Same stool	12.96	3.92	30.25	.50	3.80	.35	2.74	.48	3.69	.71	5.44	.18	1.39
Uba young ratoons—good leaves } Same stool	12.23	4.16	34.89	.46	3.79	.33	2.70	.48	3.98	.74	6.00	.13	1.12

* These chlorotic and green leaves were taken from the same stool, that is, three seperate stools.

TABLE 14

TABLE SHOWING COMPOSITION OF LEAVES AND CANE JUICES FROM CANE GROWN IN HIGHLY SALINE SOILS AT WAIANAE PLANTATION

Results: Leaves (1) Per Cent Dry Matter, (2) Per Cent of Ash; Juice (1) Parts per Mil. Juice, (2) Per Cent of Ash.

	Ash	Silica SiO_2		Lime CaO		Mag. MgO		Soda Na_2O		Potash K_2O		Sulphates SO_3		Phos. Acid P_2O_5		Chlorine Cl		Brix
		1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2	
Leaves Badila, Waianae Field 17, 1-year old, only 2 ft. high, no stalk	9.14	3.86	42.25	.38	4.23	.42	4.56	.23	2.56	2.20	24.05	.46	5.02	.51	5.57	1.04	11.48	
Leaves Badila, Waianae Field 17, 1-year old, only 2 ft. high, no stalk	9.02	..	...	.37	4.09	.47	5.27	.27	3.00	1.80	19.90	.50	5.52	.46	5.07	.90	10.05	
Leaves H 109, Field 16, Waianae, very large stalk	9.70	4.40	45.40	.42	4.26	.35	3.56	.25	2.52	2.50	25.64	.62	6.32	.43	4.51	.62	6.45	
Leaves H 109, Field 17, Waianae, very large stalk	9.78	4.28	43.80	.35	3.59	.25	2.57	.26	2.71	2.17	22.17	.51	5.20	.30	3.10	1.08	11.05	
Leaves H 109, Field 17, Waianae, large stalk	9.30	3.80	40.80	.64	6.96	.47	5.06	.25	2.68	1.78	19.13	.48	5.23	.50	5.46	1.14	12.43	
Leaves H 109, Field 17, Waianae, large stalk	10.53	...	...	.51	4.85	.29	2.72	.24	2.24	[illegible]	22.43	.34	3.24	.27	2.58	1.56	14.95	
Leaves Yellow Caledonia, Makiki, large stalk	6.32	2.72	42.98	.29	4.55	.23	3.04	..	...	...	....	.33	5.22	.30	4.83	.49	7.08	
Leaves H 109, Makiki, large stalk	5.80	1.10	18.94	.19	3.32	.18	3.12	.29	4.98	2.48	42.84	.48	8.31	.31	5.33	.51	8.83	
Leaves Yellow Caledonia, Manoa, large stalk	6.05	1.40	23.20	.23	3.82	.29	4.81	.27	4.47	2.49	41.20	.34	5.63	.34	5.66	.70	11.97	
Juice H 109, Field 17, Waianae, No. 5 leaves } Same stool	752.0	31.8	4.23	41.2	5.48	101.4	13.48	49.2	6.54	...	....	15.2	20.21	80	10.64	177.8	23.64	16.1
Juice H 109, Field 17, Waianae, No. 5 leaves } Same stool	787.0	29.8	3.79	33.0	4.19	93.0	11.82	39.8	5.06	...	....	15.1	19.19	91	11.62	187.2	23.79	...
Juice H 109, Field 17, Waianae	738.0	24.8	3.36	21.0	2.84	40.4	5.47	[illegible]	5.72	...	....	11.6	[illegible]	62	[illegible]	170.2	23.12	17.9
Juice H 109, Field 17, Waianae, No. 3 leaves	735.6	22.6	3.07	24.4	3.32	45.0	6.12	42.1	5.76	..	....	18.5	[illegible]	[illegible]	[illegible]	131.2	17.84	12.9
Juice Yellow Caledonia—Makiki Plots	643.8	26.4	4.10	22.4	3.63	47.4	7.36	28.4	4.41	...	....	6.2	9.63	97.4	15.15	136.8	21.25	16.8
Juice H 109, Makiki Plots	634.0	29.4	4.64	21.2	3.41	39.0	6.15	31.4	4.95	238.8	36.77	6.2	9.94	84.2	13.28	63.6	10.03	14.4
Juice Yellow Caledonia, Manoa Substation	609.8	14.0	2.29	21.8	3.57	60.0	9.84	32.8	5.38	190.6	31.26	18.8	30.83	40.0	6.55	45.2	7.41	19.7

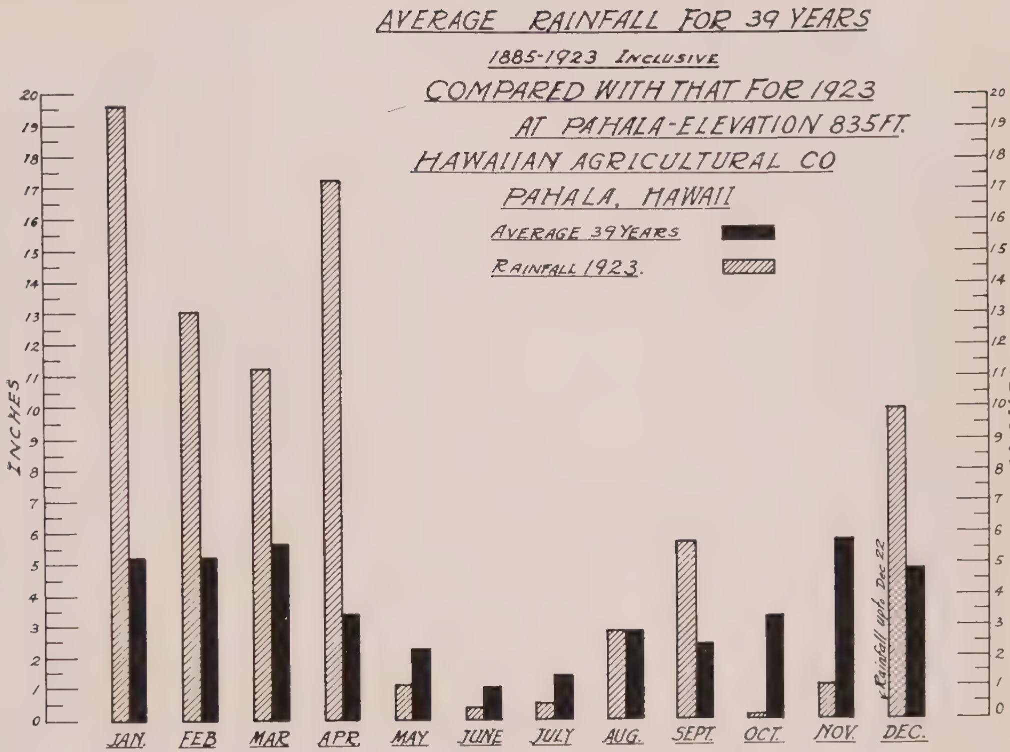
AVERAGE RAINFALL FOR 39 YEARS
1885-1923 INCLUSIVE
COMPARED WITH THAT FOR 1923
AT PAHALA-ELEVATION 835FT.
HAWAIIAN AGRICULTURAL CO
PAHALA, HAWAII
AVERAGE 39 YEARS
RAINFALL 1923.
INCHES
Rainfall upto Dec 22
JAN.
FEB
MAR
APR.
MAY
JUNE
JULY
AUG.
SEPT.
OCT.
NOV.
DEC.

Fig. 10

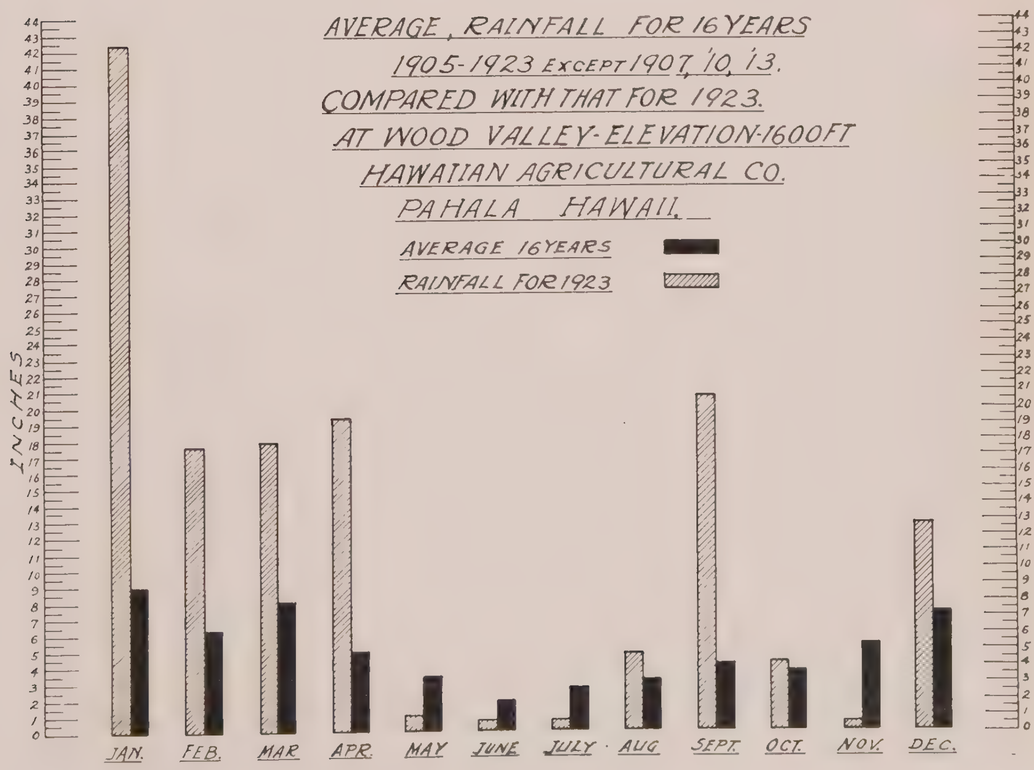
AVERAGE, RAINFALL FOR 16 YEARS
1905-1923 EXCEPT 1907, '10, '13.
COMPARED WITH THAT FOR 1923.
AT WOOD VALLEY-ELEVATION-1600FT
HAWAIIAN AGRICULTURAL CO.
PAHALA HAWAII.
AVERAGE 16 YEARS
RAINFALL FOR 1923
INCHES
JAN.
FEB.
MAR
APR.
MAY
JUNE
JULY
AUG
SEPT.
OCT.
NOV.
DEC.

Fig. 11

other with cut-back stumps of blighted Yellow Caledonia. The soil used in the pots was taken from Lower Aliona field. The following is a plan of the series:

1. Soil in pots not leached.
2. Soil leached with 5 gallons of water after placing in the tubs.
3. Same as 2 except leached with 15 gallons of water after placing in the tubs.
4. Same as 2 except leached with 25 gallons of water after placing in the tubs.
5. Same as 2 except leached with 40 gallons of water after placing in the tubs.

The blight failed to develop in any of these tubs, checks included. These along with other observations led us to conclude that the blight could not be corrected by the leaching action of irrigation water and that rainfall was not related to the location of blighted fields.

Greenhouse Experiments

In studying a problem such as the Pahala blight it is often essential and of unquestionable value to be able to reproduce it under controlled conditions. For this reason many attempts were made to reproduce the disease in the greenhouse here in Honolulu. Seed planted in Pahala soil at the Station rarely, if ever, develop the blight.

During the time we were investigating the Pahala blight problem, we were also engaged in a study of the effect of saline accumulations upon cane growth on some of our irrigated plantations. The principal salts present in these saline accumulations are the chlorides of calcium, magnesium and sodium. As covering both these problems in one experiment a series of water cultures was carried out. This work has already been published in detail (*The Hawaiian Planters' Record*, Vol. XXIX, p. 410), so that only a brief reference will be made to it here. In these experiments varying concentrations of chloride and sulphate salts were used as media in which to grow cane shoots. In the cultures to which sodium and calcium chlorides had been added there was a distinct yellow striping of the leaves, such as is observed on plants affected by Pahala blight. Neither potassium nor magnesium chlorides nor any of the sulphates produced the characteristic yellow stripes, although there was distinct chlorosis in the magnesium chloride cultures.

The concentrations of calcium chloride and sodium chloride required to produce the yellow stripes in the above experiments were far in excess of that found in the Pahala soil solutions. Also, in growing plants at these concentrations they can only be grown for limited periods, as it is difficult to grow plants successfully for extended periods at high salt concentrations. So that while these experiments indicate that sodium and calcium chlorides may be associated with the yellow striping of cane leaves, the above method falls far short of being an effective method of reproducing the blight for study.

The method of growing cane in water and sand cultures as developed by the writer, was tried in tumblers of soil. Eight-inch cane shoots were cut from seed pieces and transferred to small tumblers of Lower Aliona soil. It was thought

that the absorption of the soil solution at the base of the shoot, which sustains the plant in this method until roots develop, might reproduce the physiological disorder associated with the blight. However, all these tests were negative, that is, blight developed in none of them. The same was repeated with the plants grown under a bell jar so as to cut down the rate of transpiration. Many afternoons are overcast in the Pahala district, lowering the rate of transpiration with a slight increase in humidity. But in these experiments the plants again retained their normal green color. Still another modification in this method was made by partially shading the bell jar, but still no development of the blight. In another attempt the shoots used were lalas cut from a blighted stalk and the leaves were already in a state of itiolation. These lalas were about 8 inches in height. The old leaves retained their chlorotic stripe, but all the new leaves came out free from chlorosis.

Another experiment somewhat similar was conducted on a larger scale, using pots holding 10 pounds of soil. The soil from Lower Aliona field, and taken from one of the worst spots on the plantation, was again used. The following is a plan of this experiment:

1. Four check pots.
2. Two pots to which 5 grams sulphur had been added.
3. Two pots to which 10 grams sulphur had been added.
4. Two pots to which 20 grams sulphur had been added.
5. Two pots to which 40 grams sulphur had been added.
6. One pot irrigated with 50 p. p. m. $CaCl_2$ solution.
7. One pot irrigated with 100 p. p. m. $CaCl_2$ solution.
8. One pot irrigated with 250 p. p. m. $CaCl_2$ solution.
9. One pot irrigated with 500 p. p. m. $CaCl_2$ solution.

The irrigations with calcium chloride solution were made twice a week for the first month and then discontinued, tap water being used from this date. The plants were shoots 8-15 inches in height cut from seed pieces and planted in the pots. This experiment extended over the period of June 25 to November 2, at which time the experiment was discontinued. At this time only one plant had developed the blight and that was one of the four check pots. Apparently the disorder connected with the blight is not associated with a concentration of chlorides in the soil, although this tells us little about the effect of absorption in varying amounts.

Sand Cultures: In the large number of experiments conducted by the writer in which sugar cane has been grown in water cultures it has been often noted that the characteristic striped chlorosis will develop in the cane plant. This condition occurs irregularly, that is, it may be present in several plants, one plant or none at all in a series. It always occurs in solutions to which various nutrients have been added, that is, cane may be grown in distilled water containing no nutrients and no iron, other than that from contamination, as long as six months and retain a healthy green appearance. If to this solution nutrient salts are added, leaving off iron, chlorosis will develop and will often develop as in the cultures mentioned above even where small amounts of iron have been added. This would indicate that under certain conditions either the iron requirement of the cane is increased or where other basic nutrients are present the iron is unable

to function, as the requirement may be reduced to a minimum by leaving basic salts out of the nutrient solution and using distilled water only.

In order to throw further light on this phase of the problem the following set of sand cultures was grown. The cane used in this experiment was Yellow Caledonia and shoots were prepared in the usual manner, cut from the seed piece and transplanted to silica sand. The following nutrient solution was added to these plants as needed:

15 cc. per litre of .2 normal calcium nitrate.
10 cc. per litre of .1 normal ammonium nitrate.
8 cc. per litre of .1 normal potassium chloride.
8 cc. per litre of .2 normal magnesium sulphate.
1 cc. per litre of 8.3 grams calcium phosphate (mono).
Trace ferric citrate.

The following is a plan of the experiment:

Nutrient solution as above leaving out the iron citrate.

Nutrient solution as above, but substituting potassium sulphate for the chloride so as to have the nutrient as free of chlorides as possible.

Nutrient solution as in 2 with an addition of 100 cc. of a $CaCl_2$ solution containing 10 grams chlorine per litre.

Nutrient solution as in 1 with an addition of the same amount of $CaCl_2$ as in 3.

Nutrient solution same as in 1 plus 25 cc. of a .2 per cent solution ferric chloride per two litres.

Nutrient solution same as in 1 plus 25 cc. of a .2 per cent solution of ferrous sulphate per two litres.

Nutrient solution same as in 1 plus 25 cc. of a .2 per cent solution of ferric citrate per two litres.

Nutrient solution same as in 1 plus 100 cc. of $CaCl_2$ solution plus 25 cc. of a .2 per cent ferrous sulphate per litre.

In this experiment only the iron-deficient cultures developed chlorosis and indicated the same relationship already described.

Planting Diseased Seed: In planting seed from cane grown on the Experiment Station fields in Pahala soil the leaves have never developed the blight. In view of this a number of plantings were made in pots of Pahala soil and Station soil, using top and body seed from blighted cane at Pahala and comparing this with the same seed obtained here at the Experiment Station. In the first experiment comparison was made with body seed. Three pots holding 40 pounds of soil were filled with soil from Lower Aliona field, Pahala, and one pot with soil from the Makiki plots of the Experiment Station. Two Yellow Caledonia body seeds from Lower Aliona field and two from Makiki were planted in each pot. In the Pahala seed the buds rotted soon after germination in every case except one which grew to a height of 16 inches, although badly attacked by the blight. By germination it is meant that the buds reached a height of about one-half inch and then rotted away. The Makiki seed made very poor germination, but several grew to normal shoots with no appearance of chlorosis. All seed planted in Makiki soil made good germination and there was little or no difference between the Pahala seed and Station seed. The results of this experiment are shown in Fig. 3.

In a second experiment top seed was used. Plantings of Pahala top seed were made comparing germination in Makiki soil and Lower Aliona soil. The Pahala top seed planted in Lower Aliona soil came out 100 per cent blighted and continued so. The Pahala top seed planted in Makiki soil came out practically 100 per cent blighted, but in two weeks' time 90 per cent of the plants had thrown off the chlorosis and while somewhat undersized were free from outward appearance of the blight. This would indicate that the conditions operating to produce blight are present in the seed from blighted plants and that seed selection should be made if every possible means of combating the disease is to be utilized. It is also shown in this experiment that the disease may be reproduced for study by planting diseased top seed in pots of soil from diseased areas in the field.

As another method of reproducing the disease for study a number of diseased stumps were dug up at Pahala, the tops cut back and the whole transferred to Honolulu and replanted in soil from blight fields. New lalas developed from the buds on the cut-back stalks and all were badly blighted.

Hoffer, in studying the toxic effect of chemicals upon corn, introduced these chemicals into the stalk by inserting a tube into the tissues. This is accomplished by puncturing the stalk with a sharp cork borer. The tube is then inserted approximately to the center of the stalk and then slightly exserted to form a small reservoir from which the solution will be absorbed by the plant. Measured amounts of the solution are then poured into the tube. By this method a number of chemicals were fed by absorption into the stalks of blighted plants.

For this purpose a number of diseased stumps were planted in Lower Aliona soil and when the lalas on the stalks had reached a length of about 6 inches the tubes were inserted below the nodes on which the lalas were located. This is illustrated in Fig. 4. To one stalk a 1 per cent solution of ferrous sulphate was added, to a second a 1 per cent solution of $CaCl_2$, to another a N/20 solution of sulphuric acid, and to still another a 1 per cent solution of sodium carbonate. The leaves growing from the stalk receiving ferrous sulphate soon turned to a normal green and were the healthiest of the series. The sulphuric acid, probably by permitting a greater functioning of the iron in the plant, also showed a notable improvement in color although not equal to the ferrous sulphate. Both calcium chloride and sodium carbonate were absorbed only to a very slight degree but seemed to intensify the blighted condition of the leaves. The appearance of the roots is shown in Fig. 8.

It is believed that this little experiment shows quite conclusively that some factor interfering with the proper functioning of the iron is one of the most important factors associated with the blight. This is further indicated in the illustration, where it is shown that a stimulation in root growth also resulted from the increased leaf development obtained by the absorption of chemicals into the stalk.

Field Experiments and Sulphur Fertilization

When our investigation had reached a point where sufficient "clews" had been developed to warrant field experiments these were planned by the writer and Mr. Thompson, agriculturist at the Hawaiian Agricultural Company, and installed by Thompson. Sulphur was applied in an attempt to offset the greater absorption of chlorides by the plant provided this factor was related; to increase

the acidity of the soil and thereby the solubility and availability of acid reacting salts, primarily iron. Most chlorotic troubles are associated in some way with either an iron deficiency or a failure of iron to properly function within the plant. While our plant analyses did not signify any iron deficiency within the plant the soil analyses did show in general a higher acidity in the soil from the best fields. As a further basis for adding the sulphur there was the previous experiment already mentioned, which showed a temporary response to pouring iron sulphate solution around the roots of blighted plants. Also in our field experiment there were included heavy applications of potassium sulphate and ammonium sulphate as being milder acid residual fertilizers and as furnishing the sulphate radicle. Heavy phosphate applications were also included in an attempt to determine if a greater root development in the subsoil would increase the resistance of the plants.

These experiments were installed in the early spring of 1925 and the sulphur plots came up practically entirely free of blight and showed a great improvement in vigor, color and size, as illustrated in Fig. 5.

The effect of sulphur is further illustrated in a pot experiment conducted at the Experiment Station. A number of diseased stumps were cut back, brought to Honolulu and replanted in Pahala soil. To two of the tubs sulphur was mixed with the soil before planting, at the rate of one ton per acre. The experiment was started September 12. On October 8 the plants growing in the sulphur pots were far more vigorous and larger in size, but still had a few yellow stripes on the leaves. By October 15, this striping had entirely disappeared and the plants were normal in color and unusually vigorous. In the meantime all the checks were badly blighted and stunted in growth. This experiment was continued until November 15, at which time the plants were removed from the pots in order to observe the condition of the roots. The comparative growth of the plants in this experiment is shown in Figs. 6, 7 and 8.

It will be noted in these illustrations that in correcting the chlorosis in the leaves by injecting iron sulphate into the stalk there was a corresponding increase in root development. While the roots on this plant were not so vigorous as those on the plants grown in sulphured soil, nevertheless it is apparent that in correcting the chlorosis there is a general improvement in the condition of the plant as a whole. The conclusion is evident that the chlorosis is a primary factor in the general breakdown known as Pahala blight. It is, however, recognized that there appears a possibility of one or more other factors being associated and this is based on the remarkable stimulation in growth of so-called resistant varieties resulting from the sulphur application.

Pot Experiments With Rice

In the study of chlorosis by various investigators the rice plant, which is very susceptible, has found wide application. In view of this a pot experiment was conducted to determine whether the chlorosis and blight would be reproduced upon this plant. If so, being a short growing plant, it would have permitted a more rapid study of the problem. Clay pots holding 10 pounds of soil were filled with soil from Lower Aliona field, Pahala, and the following series of treatments applied:

1. Sulphur, 4 grams per pot.
2. Sodium sulphate, 4 grams per pot.
3. Sodium carbonate, 4 grams per pot.
4. Ammonium sulphate, 4 grams per pot.
5. Calcium carbonate, 4 grams per pot.
6. Sodium chloride, 4 grams per pot.
7. Sodium nitrate, 4 grams per pot.
8. Calcium chloride, 4 grams per pot.
9. Control, soil not treated.

These various chemicals were well mixed with the soil before planting. The chemicals were applied September 21 and planted to rice on September 22. On October 8, when all plants had reached a height of six inches, one series was changed to "wet land" culture and from this date was kept in standing water, while the second series was continued as a dry land experiment.

Throughout the experiment the ammonium sulphate pots were the most vigorous plants in both series, with the sulphur pots a close second up to the period at which in the wet land pots the lack of nitrogen retarded the growth. From this period it was surpassed by the nitrate pots. It is significant that in the dry land series the ammonium sulphate and sulphur treatments were the only pots which produced mature plants. All the rest died in about two months. The pots were photographed January 12, and are shown in Fig. 9.

Chlorosis

Chlorotic diseases of plants are often noted on agricultural crops and the conditions under which chlorosis is developed have been intensively studied. Most cases may be classified under one of the three following heads:

1. Diseases caused by bacteria or fungi often develop chlorosis. Mosaic disease is an illustration. Pahala blight has also been mentioned as a case in point, but this has been open to question.

2. Poor drainage and soil aeration developing to a point of toxicity or stagnation are often cited as causes of plant yellows.

3. Physiological or nutritional disturbances. So-called lime induced chlorosis, which is quite common in many plants grown on calcareous soils, is an example of this class.

As a matter of fact it is within the latter class that most chlorotic diseases arise. The apparent disease is merely an outward manifestation attending one or more physiological disturbances. In the majority of such disturbances the final causal factor is a deficiency of iron in the soil or in the plant.

In the cases covered by this investigation there is no indication of any infectious disease. The plants from Ewa and Waialua plantations gave no indications of being attacked by bacteria or fungi. The chlorotic plants at Pahala do finally in many cases succumb to the attacks of fungi. How great a factor the fungi are has not been determined, but in this work it has been shown that the disease may be controlled without recognition of the attacks of organisms. Also there was no indication of poor drainage in any of the areas covered here. In fact the Pahala soils are of unusually excellent physical texture. Evidence therefore shows unquestionably that the chlorotic conditions covered in this study fall in the class including physiological or nutritional disturbances.

Review of Literature

No attempt will be made at a complete review of the work on chlorosis, but merely to present several studies which are of especial interest in their relation to our own problem.

Gile[1], in a survey of chlorotic areas of sugar cane in Porto Rico, found it confined to very calcareous soils, but also noted that not all cane on such areas was chlorotic. Furthermore, he observed no chlorotic cane was to be found on slightly calcareous soils. In fact he mentions that the cane seems to favor a neutral or slightly alkaline soil where alkalinity is due to lime. These chlorotic leaves turned green in a few days after brushing with a solution of ferrous sulphate, but in several brushings were killed. In later experiments on these chlorotic areas[2], stable manure, stable manure mixed with ferrous sulphate, and spraying with a solution of ferrous sulphate were beneficial. Gile states: "There does not seem to be any definite period in the growth of the plant when it becomes chlorotic. Sometimes cane which has just sprouted is blanched and at other times the cane is unaffected until eight months old. As a rule ratoons seem to be affected more strongly and generally earlier than plant cane." All stages of chlorosis have been observed in Porto Rico, "leaves entirely ivory white, some with midrib green and others with the veins green, but the parenchymous tissue colorless." This description would apply to many chlorotic local calcareous areas, but hardly to Pahala.

Gile also studied the chlorosis of pineapples[3] in Porto Rico which he again found to be confined to calcareous areas. He found this to be a result of faulty nutrition induced by an excess of lime. According to Gile, Gris as along ago as 1843 showed that by treating chlorotic plants with ferrous sulphate they resumed their normal green color. This method as a control for chlorosis on grapevines has also been applied extensively in France and Germany. Gile applied it to chlorotic pineapples, with complete recovery of the plants.

The agriculturists at this Station have shown that chlorotic cane on a number of fields on Oahu responds remarkably to applications of iron sulphate to the leaves (Director's Monthly Report for October, 1925).

In attempting to explain this property of calcareous soils, Gile showed experimentally that neither the alkalinity nor the excessive amounts of lime were alone the cause of chlorosis, but rather it was a combination of the two factors. The ash analyses of plants showed an increased absorption of lime, creating a necessity for an increased quantity of iron and rendering average amounts of iron inactive. Sugar cane leaves, analyzed by Gile[4], showed a lower per cent of iron in the ash of chlorotic leaves (as per cent ash). He concludes from this that the chlorosis of sugar cane is accompanied by a lack of iron which is caused by a depression of the availability in the soil.

This study of chlorosis at the Porto Rico Station was later continued by Willis[5] and somewhat modified Gile's conclusions in that there was found associated with the lime in these soils the additional effect of the salts added as fertilizer. He cites the work of Kossowtsch and of Mazé, which demonstrated a change in reaction resulting from the unassimilated residue of fertilizer salts. Ammonium sulphate tended to produce an acid reaction and sodium nitrate an alkaline reaction. It will be noted from this that where nitrate of soda is applied there will be a lesser availability of iron.

TABLE 15

TABLE SHOWING COMPARATIVE COMPOSITION OF BLIGHT LEAVES FROM UNTREATED SOIL AND LEAVES HAVING NO BLIGHT TAKEN FROM PLANTS GROWN ON SULPHURED SOIL

Results Expressed in (1) Per Cent Dry Matter, (2) Per Cent of Ash

	Dry Wt. of Five Leaves	Ash	Silica SiO_2		Iron Oxide Fe_2O_3		Lime CaO		Mag. MgO		Sodium Na_2O		Potash K_2O		Phos. Acid P_2O_5		Sulphates SO_3		Chlorine Cl
			1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1
Yellow Bamboo leaves—Mid. Naahala—From sulphur plots—good leaves	37.3	8.45	3.39	40.13	.14	1.70	.44	5.20	.30	3.61	.35	4.15	2.39	27.90	.33	3.93	.69	8.18	.32*
Yellow Bamboo leaves—Mid. Naahala—From sulphur plots—good leaves	35.7	8.67	3.78	43.60	.14	1.62	.44	5.10	.18	2.10	.35	4.00	2.23	25.70	.33	3.80	.66	7.65	.32*
Yellow Bamboo leaves—Mid. Naahala—From sulphur plots—good leaves	28.0	8.97	4.00	44.60	.13	1.41	.52	5.71	.20	2.30	.35	3.98	2.30	25.61	.34	3.81	.68	7.61	.32*
Yellow Bamboo leaves—Mid. Naahala—From sulphur plots—good leaves	26.7	8.87	3.91	44.10	.12	1.40	.47	5.31	.21	2.40	.75	8.50	2.37	26.72	.35	4.00	.66	7.44	.32*
Yellow Bamboo leaves—Mid. Naahala—From sulphur plots—good leaves	29.6	9.81	4.24	43.19	.14	1.43	.51	5.21	.16	1.66	.42	4.31	2.31	23.56	.32	3.33	.61	6.27	.32*
Yellow Bamboo leaves—Mid. Naahala—From sulphur plots—good leaves	31.7	8.72	3.85	44.10	.14	1.66	.45	5.22	.25	2.95	.39	4.52	2.26	25.90	.33	3.80	.55	6.34	.32*
Yellow Bamboo leaves—Mid. Naahala—From check plots—blighted	16.9	10.94	3.94	36.04	.16	1.51	.33	3.08	.15	1.40	.82	7.54	3.72	34.01	.39	3.58	.67	4.95	.38*
Yellow Bamboo leaves—Mid. Naahala—From check plots—blighted	14.2	8.16	2.55	31.30	.14	1.80	.21	2.60	.13	[illegible]	.76	9.35	2.97	36.50	.37	[illegible]	.74	[illegible]	.38*
Yellow Bamboo leaves—Mid. Naahala—From check plots—blighted	13.6	9.33	3.50	37.53	.37	4.00	.39	4.16	.08	.88	.50	5.36	2.81	30.70	.35	3.83	.48	5.18	.38*
Yellow Bamboo leaves—Mid. Naahala—From check plots—blighted	20.1	10.41	3.94	37.80	.21	2.00	.27	2.62	.31	3.10	..	...	3.02	29.68	.46	4.40	.61	5.90	.38*
Yellow Bamboo leaves—Mid. Naahala—From check plots—blighted	10.9	9.53	3.77	39.59	..	...	.43	4.52	.30	3.15	.36	3.84	2.36	24.80	.41	4.29	.59	6.18	.38*
Yellow Bamboo leaves—Mid. Naahala—From check plots—blighted	13.1	9.47	3.35	35.40	.13	1.38	.33	3.56	.37	3.88	.37	3.92	3.23	34.10	.37	3.92	.65	6.90	.38*
D 1135 leaves—Lower Aliona—From sulphur plots—good leaves	19.8	9.59	4.45	46.40	.13	1.34	.26	2.71	.36	3.81	.28	2.93	2.96	30.84	.44	4.64	.54	5.60	.60*
D 1135 leaves—Lower Aliona—From sulphur plots—good leaves	21.7	9.60	4.03	41.96	.14	1.47	.20	2.12	.39	4.13	.51	5.31	2.78	29.01	.43	4.48	.53	5.53	.60*
D 1135 leaves—Lower Aliona—From sulphur plots—good leaves	20.4	10.58	4.47	44.39	.14	1.37	.27	2.66	.37	[illegible]	.47	4.64	2.94	[illegible]	.39	3.85	.70	7.85	.60*
D 1135 leaves—Lower Aliona—From sulphur plots—good leaves	21.2	10.44	5.08	48.70	.14	1.34	.26	2.49	.38	3.70	.92	8.84	2.79	26.74	.40	3.88	.46	4.42	.60*
D 1135 leaves—Lower Aliona—From check plots—blighted	8.4	9.76	3.63	37.18	.20	2.07	.18	1.89	.38	3.91	.56	5.72	3.34	34.23	.47	4.89	.58	5.99	.76*
D 1135 leaves—Lower Aliona—From check plots—blighted	5.2	11.30	4.51	39.91	.28	2.53	.25	2.23	.69	6.14	.80	7.10	3.44	30.56	.50	4.43	.55	4.91	.76*
D 1135 leaves—Lower Aliona—From check plots—blighted	4.8	13.13	5.78	43.34	.29	2.21	.27	2.07	.61	4.57	..	...	3.65	27.40	.51	3.80	.57	4.27	.76*
D 1135 leaves—Lower Aliona—From check plots—blighted	3.0	10.44	2.96	28.39	..	...	.30	2.89	1.14	10.95	1.12	10.76	3.60	34.48	.54	5.16	.52	5.00	.76*
Yellow Caledonia leaves—From pot experiment—sulphured—good leaves	..	10.90	4.92	45.22	.19	1.78	.44	4.04	.31	2.86	.40	3.73	2.54	23.42	.44	4.10	.50	4.65	..
Yellow Caledonia leaves—From pot experiment—sulphured—good leaves	..	9.09	3.20	35.19	.14	1.58	.34	3.81	.57	6.28	.35	3.82	2.83	31.15	.35	3.57	.48	5.30	..

* Chlorine determination made on a composite sample from each set.

In experimentally studying this point Willis showed that nitrate of soda, calcium carbonate and ammonium phosphate, which in themselves or by virtue of an unassimilable iron are the cause of the precipitation of iron, were associated with chlorosis, while the plants supplied with ammonium sulphate were a normal color. From this he suggests that the unassimilable residues are primarily the cause of chlorosis and that the reaction of the soil is a secondary factor.

McCall and Haag[6] at the Maryland Experiment Station have shown that in sand cultures chlorosis may develop where calcium or sodium nitrate is used within the reaction range of pH 4.02 to 7.0. Adding iron to the cultures at this reaction did not improve the condition of the plant, but by increasing the reaction with sulphuric acid the plants became a normal green color. It is therefore shown that chlorosis or faulty metabolism resulting in chlorosis may be possible at reactions below neutrality, and since the reaction of many of the Pahala soils is on the acid side of neutrality this is a case in point.

As showing the complexity of chlorosis the work of Kelley[7] and Cummins on the mottled leaf of citrus trees may be mentioned. In this case conditions are directly opposite, as there appears to be a *deficiency* of calcium or an inability of citrus trees under certain conditions to obtain their lime requirements.

Malherbe[8] has made some very interesting observations in South African plum and apricot orchards, which appear to be somewhat related to Pahala conditions. He noted in orchards affected by chlorosis that the condition was always intensified following heavy applications of basic alkaline fertilizers. Surface soil samples taken from about healthy and chlorotic trees showed a greater acidity in the former. These soils were not calcareous soils, and like the Pahala soils, none strongly alkaline and some slightly acid. On these chlorotic trees iron sulphate spray killed the leaves and when applied to the soil gave only temporary improvement. On the other hand, changing from basic fertilizers, primarily basic slag, to residually acid fertilizers such as ammonium sulphate, superphosphate and potassium sulphate, these orchards were completely restored to normal. He advised the use of sulphur as a fertilizer in acute cases.

In Antigua, West Indies, cane fields, what are known as gall patches, are often observed. The plants on these areas are often chlorotic and the soils calcareous. Tempany[9], after a study of this problem, suggested that this condition was not due to excessive lime, but to sodium carbonate formed by a reaction between the lime and the saline material, principally sodium chloride, in the soil solution. The gall patches showed a greater alkalinity than the surrounding areas in which cane made good growth.

It is evident from a review of the literature that the results obtained upon the Pahala soil by sulphur fertilization are not only theoretically sound, but are also supported by other investigations.

The results obtained in our rice experiment are rather striking and it is of interest to compare this with the work of Gile, Willis and Carrerro, already cited. During the early stages of growth the submerged pots showed active stimulation from the sulphur treatments. At the time the plants were photographed the sulphur pots were about the same as the checks and plainly showed the effect of the lack of nitrogen. The value of sulphur and ammonium sulphate, and the

same might also apply to any acid fertilizer, is shown in the "dry land" pots. The check plants and all those treated with alkaline fertilizers made only a short growth, eight inches, and then died. Both the sulphur and ammonium sulphate would increase the availability of iron provided this was a retarding growth factor, while in the submerged pots there would be a reducing environment conducive of maximum availability of iron under the conditions existing even in the presence of alkaline salts. Other than the check pots and the sodium nitrate pots there was little chlorosis of the rice plants. Preceding death the leaves turned a brownish color rather than the characteristic chlorotic yellow.

As a further step in the study of this problem some explanation of the conditions which operate following sulphur fertilization was sought. Comparative analyses of chlorotic leaves from check plots and green leaves from sulphured plots in the field experiments were made. Also a short soil study was conducted. The comparative composition of the leaves is given in the following Table 15:

The first column, showing the comparative weight of the leaves, is of especial interest and shows very clearly the relative stunting in growth resulting from attacks of the blight. The reduction in leaf area in blighted plants even in the absence of chlorosis would materially reduce the sugar-producing activities in the leaves. In general, the sulphur has materially reduced the ash content of the leaves; the potash and chlorine also show some reduction. Other than this, taking into consideration the wide variations, there is little difference in the composition of the leaves. The iron determinations do not indicate that the iron content of the leaves has been increased by the sulphur, but rather making the deduction from averages there is less in the leaves from the sulphured plots. This applies both to the Yellow Caledonia and the D 1135. In considering these results as relative composition of the ash, Yellow Caledonia, the susceptible variety, shows a higher silica, lime and sulphate in the sulphured plants.

The soil changes induced by sulphur fertilization have been the basis of numerous investigations. Sulphur itself is more or less inert and its action in the soil follows its oxidation, usually bacterial, to sulphuric acid. Lipman has suggested using this property of sulphur as a means of increasing the availability of phosphate. Others have suggested sulphur as a neutralizing agent for alkali in alkali soils. Numerous references could be cited in which response to sulphur fertilization has been obtained, but such have been on sulphur deficient soils. There is no deficiency of sulphur as a plant food in Pahala soils. In fact the Mudflow field which has always been free of blight is lower in water soluble sulphates than the blighted fields. The excellent response to sulphur at Pahala is not related to any deficiency of sulphate as plant food.

Another application of sulphur to agriculture has been shown in adjusting soil reactions to ranges most favorable to definite plants or crops and unfavorable to injurious organisms. The control of potato scab by means of sulphur fertilization, by which the reaction of the soil is increased to a point where the fungi cease to operate, is a case in point. Whether the results of the sulphur treatments at Pahala are in any way associated with the control of fungi has not been determined. It is, however, significant that the leaves of the plants growing on the sulphured plots are free from any visible attacks of organisms in direct contrast

to the plants in the check plots. It is believed, however, that this is due to the greater resistance or vitality of the plants on the sulphur plots.

Some indication of the chemical changes brought about in the Pahala soil is shown in the following tables. This soil is from one of the worst spots in Lower Aliona field and is that used in the pot experiments. The sulphur had been well mixed with the soil and kept at optimum moisture content for four months previous to the analyses.

In Table 16 is given the solubility of the more important soil constituents in 1 per cent citric acid, which solvent has been extensively used by this laboratory in estimating soil constituents available to sugar cane. In Table 17 is given the composition of the soil solution obtained by the displacement method. This solution represents that in which the plant roots would actually be growing in this soil.

TABLE 16

Comparative Composition of Citric Extracts

Expressed as Per Cent Dry Soil

	Check	Sulphur
Silica (SiO_2)	.507	.520
Manganese oxide (Mn_3O_4)	.050	.040
Calcium oxide (CaO)	1.194	.962
Magnesium oxide (MgO)	.289	.334
Sulphur trioxide (SO_3)	.203	1.220
Potash (K_2O)	.105	.059
Phosphoric acid (P_2O_5)	.2045	.1380
Soil reaction pH	7.16	5.39

TABLE 17

Comparative Composition of Soil Solution

Expressed in Parts per Million of Solution

	Check	Sulphur
Total solids	2440	7440
Non-volatile solids	1316	5940
Volatile solids	1124	1500
Silica (SiO_2)	25	65
Iron-aluminum oxides (Fe_2O_3-Al_2O_3)	5	9
Phosphoric acid (P_2O_5)	.4	1.5
Manganese oxide (Mn_3O_4)	none	trace
Lime (CaO)	248	940
Magnesia (MgO)	145	941
Sulphur trioxide (SO_3)	223	3635
Sodium (Na_2O)	417	566
Potash (K_2O)	135	108
Chlorine (Cl)	140	272
Bicarbonates (HCO_3)	36	18
Carbonates (CO_3)	none	none
pH of soil suspension	7.16	5.39
pH of soil solution* (immediate)	8.18	5.2–6.0
pH of soil solution* (next day)	8.18	8.01

* The reaction of the soil solution was determined immediately after extraction, without allowing contact with air, beginning with the first 5 cc. and continuing to 100 cc. The reaction of these separates varied irregularly from 5.2 to 6.0. After standing 24 hours the entire soil solution extracted had changed to 8.01. The usual method of determining soil reaction involves the suspension of the soil in water at the ratio of 1-3 and this figure is that given in the table as soil suspension.

There is little of importance shown in the 1 per cent citric acid extracts other than that the sulphur has undergone rapid sulphofication as shown by the increase in acidity. On the other hand, the concentration of all constituents with the exception of potash and bicarbonate in the soil solution has been increased. The difference in availability or solubility of iron would be greater than that indicated by the analyses, as at the reaction developed by the sulphur the iron would be combined rather rapidly with phosphate which is present in large quantities in this soil. The data show beyond question that comparatively large amounts of soluble iron would be continuously supplied to the roots in the environment created by the sulphofication of the sulphur.

As showing how closely related the response of blighted plants is to the change in reaction wrought by the sulphur, the following observations are of interest. In the sulphur plots there are to be found occasional stools which are chlorotic yet not blighted. Samples of soil were taken about these plants for comparison with that taken directly around plants entirely free from any chlorosis. These samples are from Lower Aliona field, and the soil samples are from neighboring stools:

Good plant, sulphur plot, pH	5.56
Chlorotic plant, sulphur plot, pH	7.08

From this it is evident that the inability to thoroughly incorporate the sulphur with the soil has permitted scattered stools to fail to respond to the sulphur treatment. Anent this significance of soil reaction, another set of soil samples was taken from an area in Middle Naahala field, untreated soil, where there was a spot of badly chlorotic cane surrounded by plants which at least at the time of sampling were not showing any indications of a disturbance. The pH of the soil around the chlorotic cane was 7.33 while that around the good cane was 6.66. The preceding data would also account for the variable results given in the reactions obtained in the soil survey, to which attention was called in the discussion of this data, and give sufficient grounds for accepting averages in spite of the variations. Three samples of soil taken within an area of one acre in Middle Naahala field showed a variation in reaction of pH 6.06 to pH 7.33 and as stated above there appeared to be greater soil acidity in the good spots.

Discussion

The results indicate that the chlorosis associated with Pahala blight is caused by an entirely different set of conditions than that of Ewa and Waialua plantations. At the latter there are two definite forms, a temporary and a permanent chlorosis. The former, which occurs only on young ratoons, may be explained on the following theory: Nitrogen is held off maturing cane for a considerable period preceding the harvest. The nitrogen content of the soil is therefore at a minimum until the regular fertilization of the ratoons. Also as soon as the cane is harvested the soil moisture evaporates rapidly from the soil surface, increasing the concentration of soluble material around the roots of the new forming shoots. The young shoot therefore begins to feed upon a nutrient solution high in basic material and low in nitrogen, a ratio usually conducive of chlorosis. This is shown

by the high ash content of the yellow leaves and further by the fact often noted on the plantations that early fertilization or even early irrigation of the ratoons is of value as a corrective measure.

The permanent forms of chlorosis on these alkaline and calcareous areas appear to be a result of the lower availability of iron in the soil and conditions in the plant which operate against its activity, namely, a greater absorption of inorganic material by the plant and transported to the leaves. As Kutsunai has shown, these plants may be restored to normal by treating the leaves with iron sulphate. In the alkaline fields where coral is absent the plants should respond to acid fertilizers such as sulphur or ammonium sulphate. As a matter of fact, Denison, of the agricultural department, in an observation test showed that the plants at Waialua plantation responded to sulphur fertilization in one month. This is much slower than treating the leaves, but it is permanent. Whether the use of acid fertilizers could be extended successfully to the coral fields is open to question, but theory favors the use of ammonium sulphate in preference to nitrate of soda on such fields.

The Pahala fields are entirely free of coral. Their reaction is in no case strongly alkaline. In fact many of the soils in which the cane is chlorotic are slightly acid. As a related case here in the Islands, the chlorosis of pineapples on the manganiferous soils may be cited. These soils are in all cases acid soils, yet pineapple plants are almost universally chlorotic on such areas. It should be mentioned, however, that cane has never been known to develop chlorosis on the manganese soils and the writer has often seen it growing on such types. The Pahala soils are the only soils on record in which sugar cane has shown chlorosis on acid soils.

One very significant observation in our study of the problem was that the soil solution always appeared to be more or less colloidal, which, however, is not true of the soil solution from the Mudflow field which has always been entirely free from blight. In using the soil solutions as culture media in which to grow cane shoots it was noted that after a certain period there was a coagulation of this colloid and from this time the roots developed rapidly. It was suspected at the time of the experiments that this was colloidal silica. Since then it has occurred to the author that this may have been colloidal iron or a colloid which interferes with the assimilation of iron by the roots. Gile[10] has shown that rice plants cannot assimilate colloidal iron. In our own soil work we have shown that between reactions of pH 6.0 and 7.5, which range covers most of the Pahala soils, iron (ferric) is present in solution only in the colloidal form. There would be little opportunity for ferrous iron to be present in such open soils as those at Pahala. There is a strong possibility, therefore, that conditions in some of the Pahala soils operate toward minimum availability.

In soils within the reaction range at which iron is not in solution plants depend upon the carbon dioxide liberated in root respiration to obtain such insoluble materials. Carbon dioxide, the product of root respiration, is directly dependent upon the normal development of chlorophyll in the leaves. Chlorotic leaves will operate toward retarded root respiration and will limit the rate and amount of carbon dioxide produced by the roots. It is therefore evident from

this that the poor leaf development on the plants at Pahala will limit root development, promote a general breakdown of the plant and predispose it to a ready invasion of the fungi which appear to be associated with the final blighting of the cane. It is thus shown that chlorosis produced by malnutrition in the leaves is reflected back to the roots. We have thus far been unable to discover any toxic condition in the soil which would account for the poor root development in blighted plants. All evidence to date strongly indicates that the poor root development is secondary to the disturbance in the tops and that roots are just as dependent upon the food supplied to them by the leaves as they are upon that which in themselves they absorb from the soil.

It is believed from our observations with sugar cane that chlorides, probably only the sodium and calcium chlorides, are in some way associated with chlorosis not as a question of concentration in the soil solution but as an unbalanced absorption by the plant. The chlorosis, an iron deficiency, is merely the final outward manifestation of such a disturbance. In our field experiments in which D 1135 variety was used, which variety has always been considered blight resistant, we obtained remarkable response to sulphur fertilization. This response was obtained on blighted as well as unblighted plants in diseased areas. It is evident from our field experiments that D 1135 does not possess the degree of resistance which has been credited to it, although it is more resistant than any other variety. This is probably due to the fact that the outward manifestation of the blight, the chlorosis, is often lacking or is thrown off at an early stage in its growth. In a replanted area in Lower Aliona there were many D 1135 plants in the control, unsulphured areas, which were not chlorotic and yet were no larger in size than the chlorotic plants, while in the sulphured area the plants were uniformly much larger in size and of a richer green color.

Another indication that factors other than the reaction range at which iron is at lowest availability are involved, is that at this same reaction where the cane is growing in distilled water chlorosis does not develop. It develops only when there are present soluble nutrient salts which operate against the activity of the iron.

Conclusions

1. Pahala blight is the result of a physiological or nutritional disturbance induced by soil conditions.

2. With the exception of phosphate in the subsoil, plant food availability is very high in Pahala soils.

3. The principal difference between the soils from blight and no blight fields is the slightly lower hydrogen ion concentration and in the lower hydrogen ion concentration of the subsoil as compared to the top soil in the former.

4. Comparative plant analyses indicate that a greater ash and chlorine content in the blighted plants is related to the chlorosis.

5. In a comparison of chlorotic plants from coral and other alkaline soils with plants grown on Pahala soils a similarity in composition was noted. Wide differences were, however, shown in the soil environment. The outward manifestation, namely, chlorosis or iron deficiency, is similar. The causal environment is different.

6. The disturbing factor may be carried in the seed, which, however, soon disappears if planted in good soil. If planted in blight soil the plant is weakened from the germination point.

7. Seed from blighted plants should never be used, in view of their lower vitality.

8. Sulphur fertilization entirely corrects the causal environment associated with Pahala blight, in that it increases the acidity of the soil and thereby the availability of the acid reacting salts, notably iron. A greater efficiency of iron in the plant is also produced.

Acknowledgments

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Fig. 1 A

Fig. 1. B

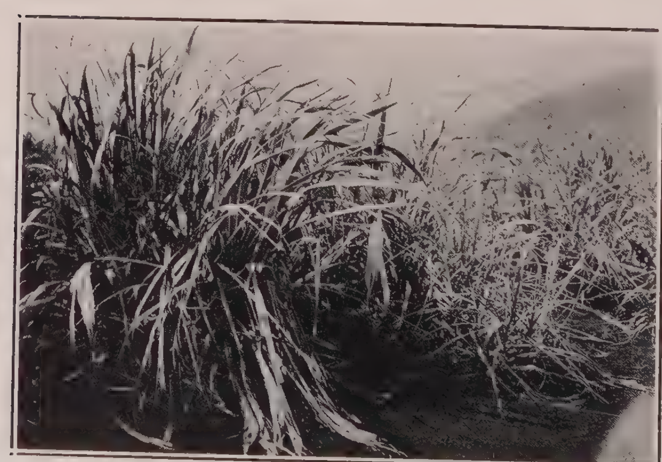

Fig. 1. C

Three views of Yellow Caledonia cane affected by Pahala blight. A and B show the disease quite uniformly scattered over the field. C shows a good stool in badly blighted field.

Fig. 2. Showing growth of cane shoot, two weeks period, in soil solutions. Reading from left to right: 1—Yellow Caledonia, soil solution from lower Goodale. 2—Yellow Caledonia, subsoil solution from lower Goodale. 3—Yellow Caledonia, soil solution from Wood Valley. 4—Yellow Caledonia, soil solution from Mudflow. 5—D 1135, soil solution from Lower Goodale. 6—D 1135, subsoil solution from Lower Goodale. 7—D 1135, soil solution from Wood Valley. 8—D 1135, soil solution from Mudflow.

Fig. 3. Showing comparison of Pahala and Station seed in Pahala and Station soil. Left—Pahala seed—Pahala soil (typical blight). Center—Left—Pahala seed—Station soil; right—Station seed—Station soil. Right—Station seed—Pahala soil.

A B

Fig. 4. Showing method of feeding chemicals into the cane stalk.

Left—1 per cent sodium carbonate solution.
Right—N/20 sulphuric acid solution.

Left stalk—1 per cent iron sulphate solution.
Right stalk—1 per cent calcium chloride solution.

Fig. 5A. D 1135 plant cane six months old, Lower Aliona field. On left, first row of control cane, untreated. On right, first row of cane fertilized with sulphur. Sulphur applied before planting.

Fig. 5B. D 1135 plant cane six months old, Lower Aliona field. In foreground, control cane, untreated. In background, cane fertilized with sulphur applied before planting. The difference in color is plainly visible. The cane in the foreground is chlorotic, but there is little blighted-wilted-cane.

Fig. 6. Same plants as shown in Fig. 7. Left—fertilized with sulphur. Right—untreated control. Photograph taken at one month period after transplanting stumps. This being a closer view than Fig. 7, the difference in color is plainly visible, as is also the typical ''damping off'' on the smaller shoots.

Fig. 7. Yellow Caledonia diseased stumps brought from Lower Aliona field, Pahala, and replanted in Lower Aliona soil at Experiment Station. All plants two months old. Left—Soils received sulphur, one ton per acre before planting, and plants entirely recovered. Right—Soils untreated—no recovery.

Fig. 8. Showing comparative root growth. Left—Two plants from sulphur pots. Center—1 received $Fe SO_4$ in the stalk; 2 received $H_2 SO_4$ in the stalk. Right—Two plants from control—untreated pots.

Fig. 9. A.

Fig. 9. B.

Showing (upper) dry land rice and (lower) submerged rice. Pots from left to right: sulphur, sodium sulphate, sodium carbonate, ammonium sulphate, calcium carbonate, sodium chloride, sodium nitrate, calcium chloride, and check.

Sugar Prices

96° Centrifugals for the Period December 18, 1925, to March 9, 1926

Date	Per Pound	Per Ton	Remarks
Dec. 18, 1925......	4.08¢	$81.60	Cubas.
" 21...........	4.11	82.20	Cubas.
" 23...........	4.14	82.80	Cubas.
" 30...........	4.195	83.90	Cubas, 4.18, 4.21.
" 31...........	4.21	84.20	Cubas.
Jan. 5, 1926......	4.125	82.50	Cubas, 4.14, 4.11.
" 7...........	4.11	82.20	Cubas, 4.14; Porto Ricos, 4.08.
" 11...........	4.14	82.80	Cubas.
" 12...........	4.11	82.20	Cubas.
" 18...........	4.125	82.50	Cubas, 4.11, 4.14.
" 19...........	4.14	82.80	Cubas.
" 26...........	4.225	84.50	Porto Ricos, 4.21; Cubas, 4.24.
" 27...........	4.24	84.80	Cubas.
" 28...........	4.27	85.40	Cubas.
" 30...........	4.24	84.80	Cubas.
Feb. 4...........	4.27	85.40	Porto Ricos.
" 11...........	4.255	85.10	Cubas, 4.27; Porto Ricos, 4.24.
" 15...........	4.225	84.50	Cubas, 4.24, 4.21.
" 16...........	4.18	83.60	Porto Ricos.
" 23...........	4.14	82.80	Cubas.
March 2...........	4.095	81.90	Cubas, 4.11; Porto Ricos, 4.08.
" 3...........	4.08	81.60	Porto Ricos.
" 8...........	4.05	81.00	Porto Ricos.
" 9...........	4.02	80.40	Porto Ricos.